ASTRONOMY

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The First Colony on Mars

Get Ready to Observe Halley's Comet

The Anatomy of a Nebula

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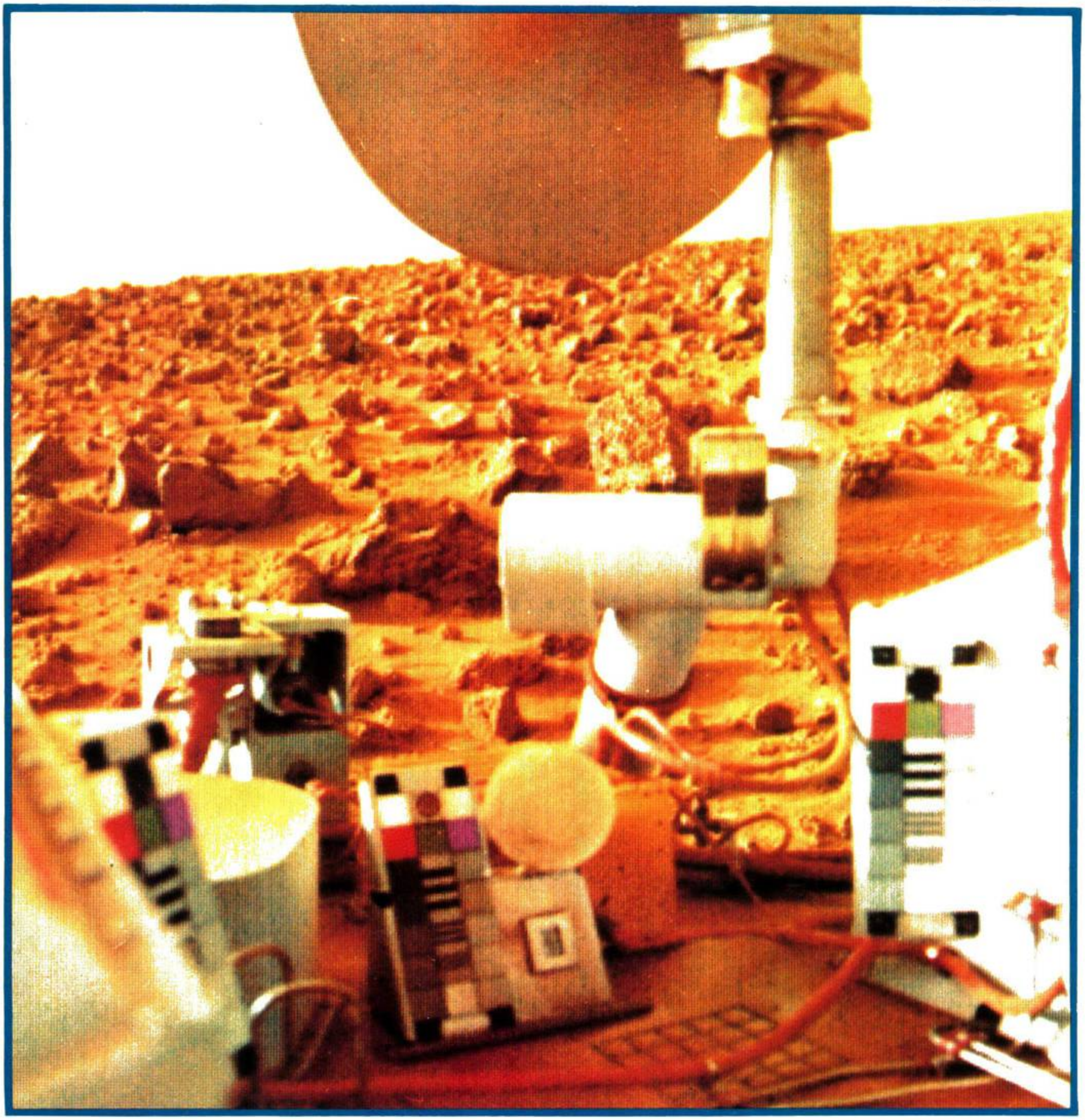

The Surface of Mars

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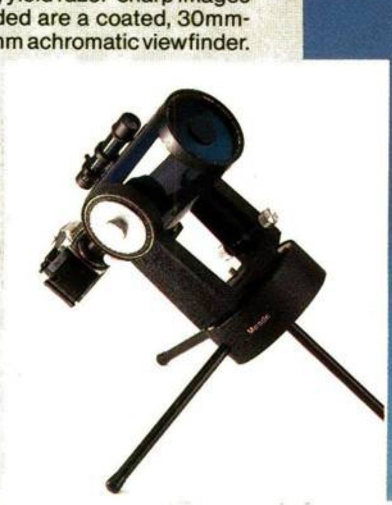

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(3) Model 628: 6" f/8
(4) Model 826: 8" f/6

than meets the eye.

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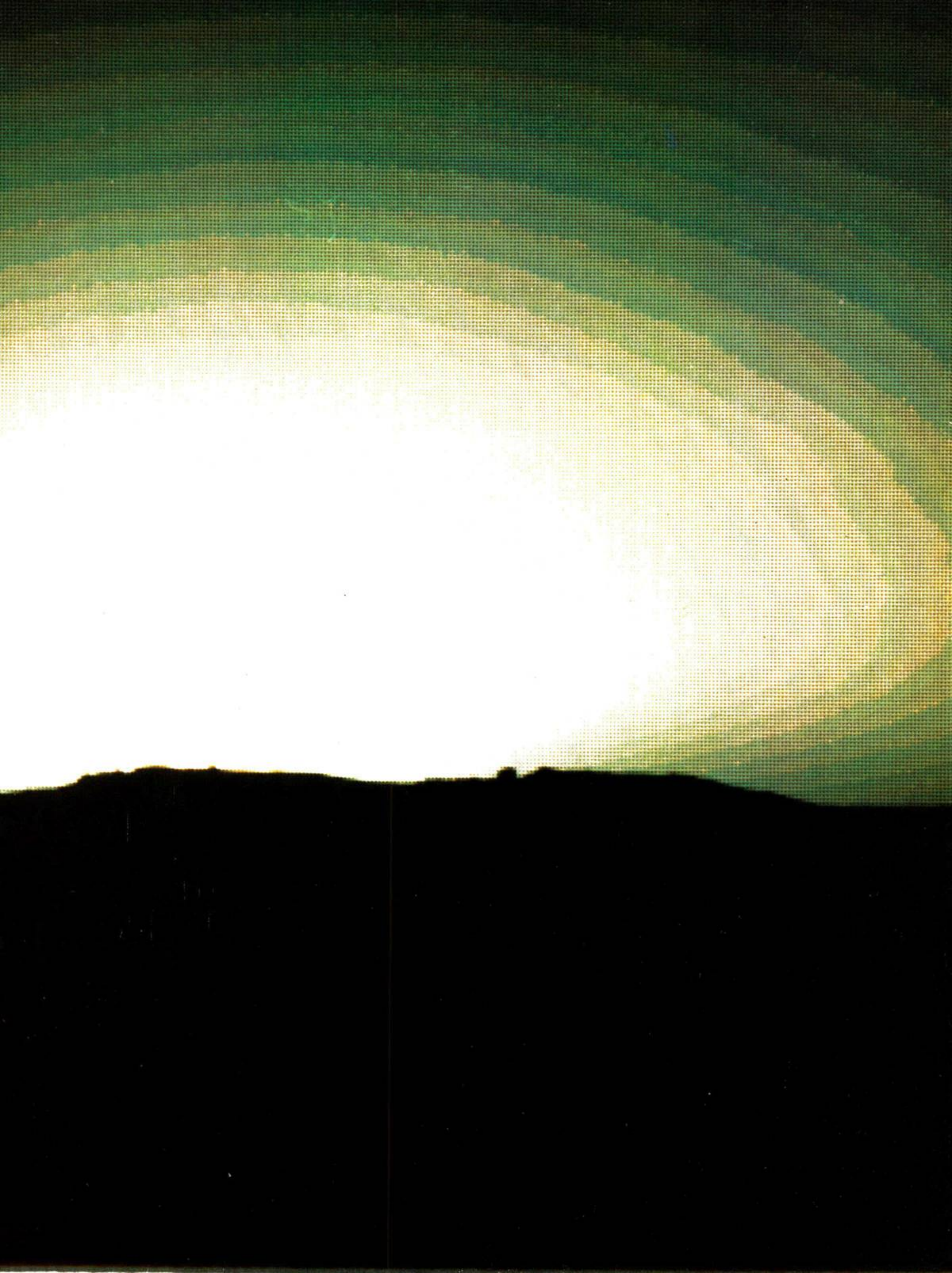

ASTRONOMY

Vol. 13, No. 6 June 1985

The World's Most Beautiful Astronomy Magazine • Established by Stephen A. Walther

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Cover: The Red Planet has long beckoned across millions of miles of space, drawing human hopes and yearnings. Who hasn't at one time or another envisioned visiting there and strolling across the dusty martian landscape under a peach-colored sky? This month, ASTRONOMY brings the dream a little closer to reality when it takes you on an imaginary trip to the first colony on Mars. These pages: Sunset over Chryse Planitia as seen by the Viking 1 lander. JPL/NASA photos.

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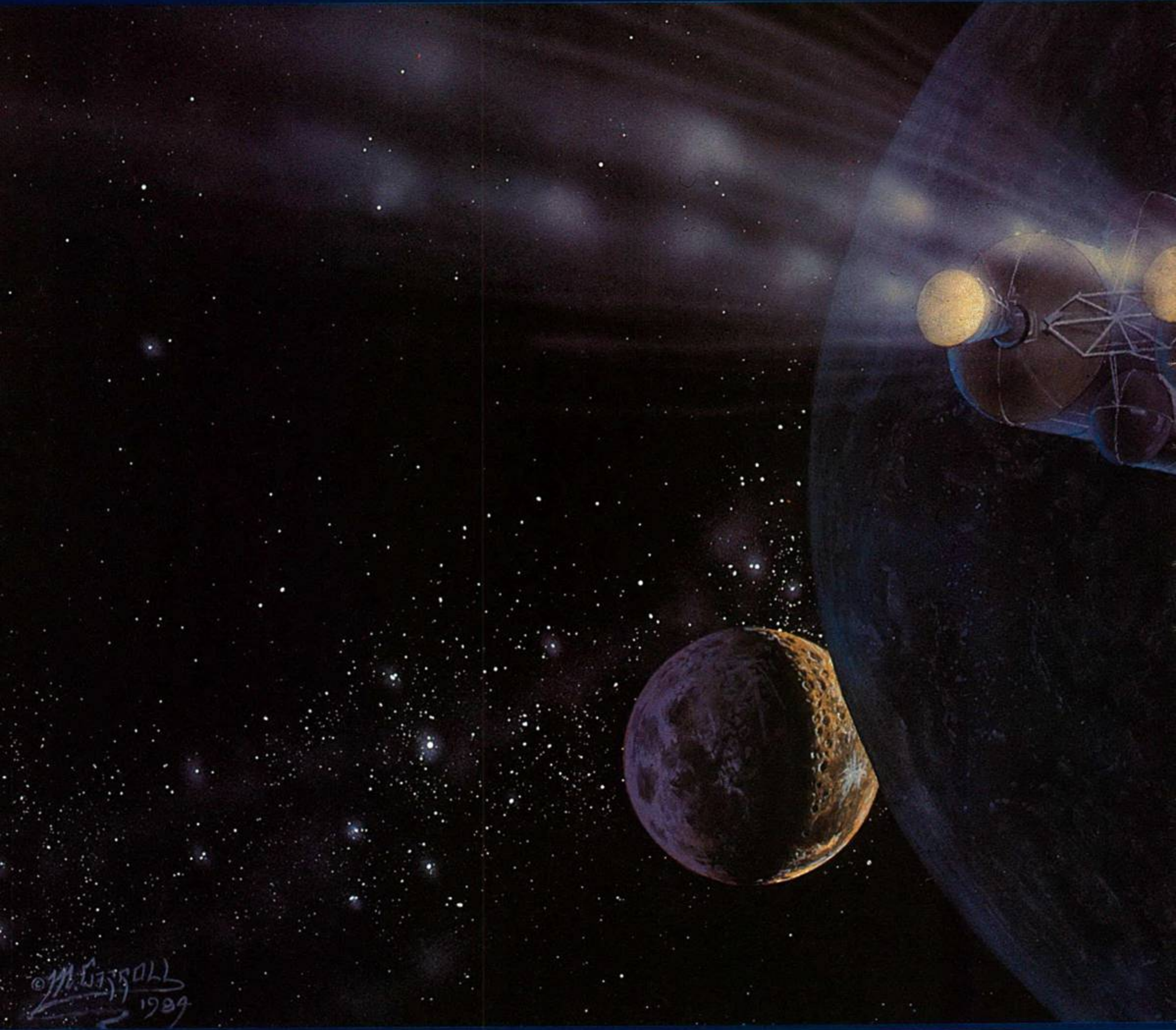
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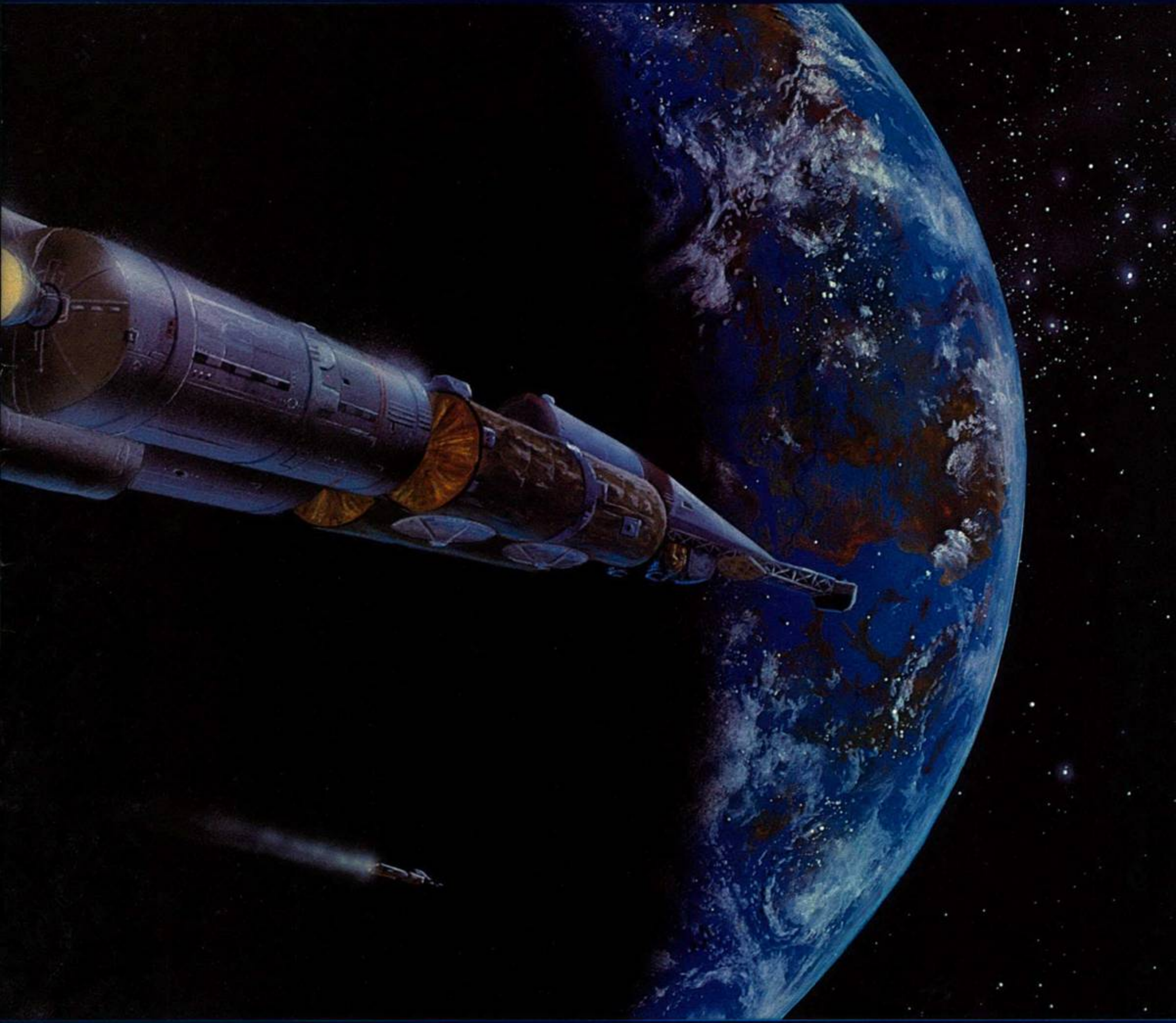
The First Colony on Mars



With a steady push from expendable booster rockets, two of the Mars transport ship's three modules leave Earth orbit and begin their long coast outward toward the Red Planet. After reaching escape velocity, the modules will discard their booster stages and link up to form a large Y-shaped ship, which will then be set spinning to provide artificial gravity. Six months ahead: the Red Planet. All paintings by the author.

By
Michael W. Carroll

NASA
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They're here already.

Martians have been living on Earth for months — perhaps even years. Haven't you noticed them?

If you haven't, it's probably because you don't know what to look for. Here's a hint: Set your sights low — about two feet off the ground, in fact. And look everywhere.

Give up? They're *toddlers.*

That's right. The men and women who will inhabit the first permanent colonies on Mars are among today's toddlers.

It's difficult to project what the first manned landings on Mars will be like, let alone more advanced efforts like colonies. How will we get people to and from Mars on a routine basis? What will everyday living be like on a alien world? What wonders will we explore there and how will we travel?

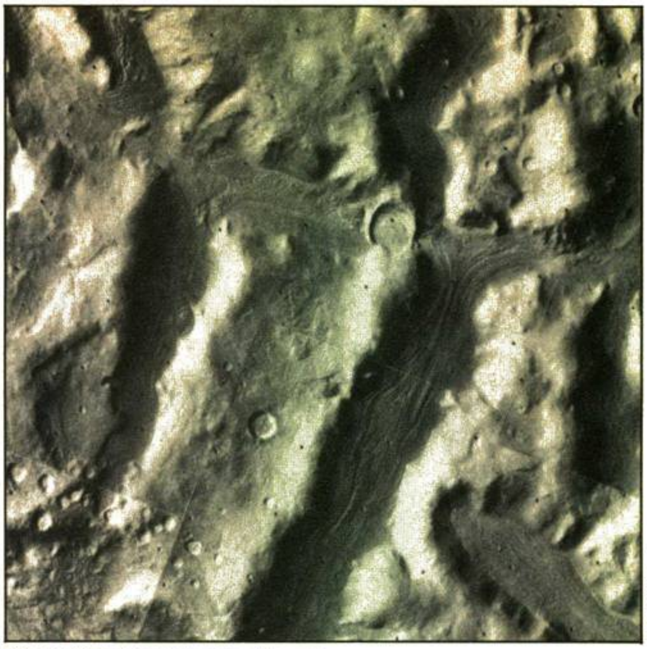
NASA isn't the only one thinking about such problems. Last summer, a group of scientists and engineers from diverse backgrounds met in Boulder, Colorado to advance "The Case for Mars." The second of such meetings, last summer's gathering focused on outlining the technology and direction needed to achieve one goal: a permanent, self-sufficient manned presence on the martian surface.

. . . Our gleaming, Y-shaped structure wheels lazily through the velvet void. Launched from Earth orbit as three separate units, the modules rendezvoused, docked, and began to pinwheel. For the duration of the long journey to Mars, the spin will create an artificial gravity equal to that on Mars: about a third of Earth-normal. This will keep the passengers in top physical shape and make the trip more comfortable.

The ship has taken people out to the colony before. It is designed to cruise in an orbit that sails by Mars and then loops directly back to Earth. It is truly an interplanetary transport. The Mars flyby trajectory is simple and saves fuel, but it has a price: while the journey to Mars takes about six months, the return to Earth is a lonely year-and-a-half voyage, due to the orbital positions of the two planets . . . .

Before these ships went into service, expendable craft had established beachhead bases on Mars. The earliest outposts placed on this New World were humble indeed. Using modules originally designed for the Space Station, the Mars base was mostly underground — a tactic adopted by the colony, too. Soil is a good shield against the solar and cosmic radiation that beats down on the martian surface. The outposts had solar and nuclear power, weather stations, fleets of rovers. Like the colony, the early bases were international. Cooperation within the world community made finances less of a burden, and a vast international reservoir of expertise could be called upon.

Any settlement on the distant Red Planet requires a reliable transportation link with home. The interplanetary transport ship envisioned by the scientists and engineers at the Case for Mars conference consists of three self-sufficient modules linked together to form a trefoil or Y-shape. Assembled in Earth orbit, each module spans 60 meters — the size of a 20-story building. Three expendable auxiliary booster rockets accelerate each module out of Earth orbit up to escape velocity for the long coast to Mars. After boost, the auxiliary stages separate, and the three modules are joined together and set spinning. As they spin, one side always faces the Sun; this side houses the phased-array communications equipment, solar furnaces for heating and power, propellant tanks, and engines derived from the Space Shuttle's orbital maneuvering system. The shadow side houses two habitats — living quarters — on each arm. These habitats are developed from Space Station technology. The shuttle craft which take passengers down to the surface are cradled behind the habitats, as are life-support consumables.



JPL/NASA photo

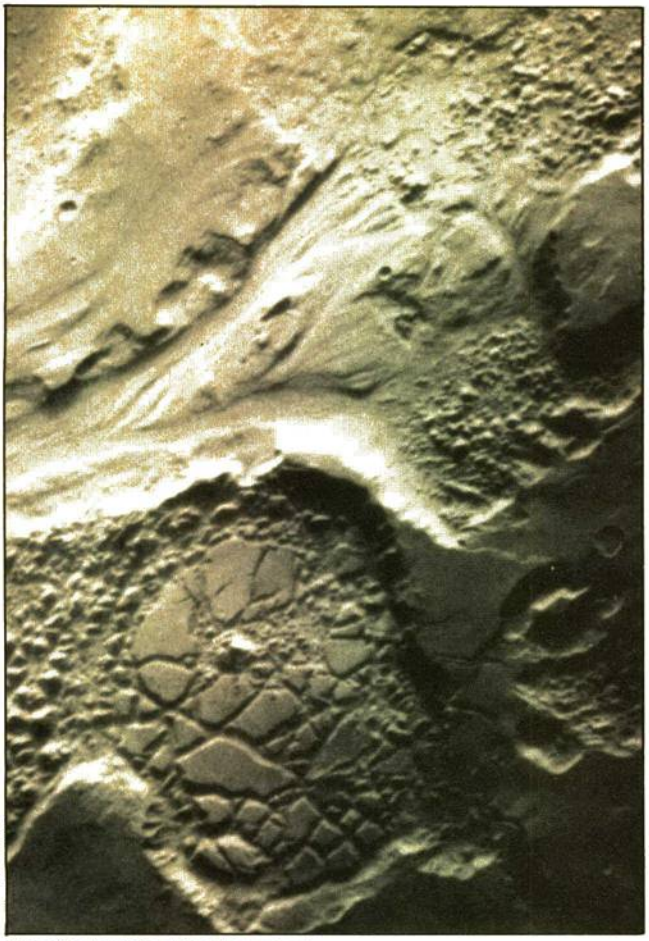
Nilosyrtis: ground-water flows?

As the transport ship arrives at Mars, one of the three shuttle craft separates and prepares to ferry its cargo of passengers down to the surface. Another shuttle has already started its descent, and the third will soon follow. Meanwhile, three shuttles from the previous transport flight have lifted off from the colony and are on their way up to dock with the transport ship, which will return them to Earth.

The trip to Mars is long and potentially treacherous. In addition to cosmic rays, temperature extremes, and the general danger of living in a vacuum, the crew faces varying levels of radiation from the Sun. Close to the Earth, spacefarers are protected from much (though not all) harmful solar radiation by the Earth's magnetosphere, a tenuous "cage" of magnetic fields which deflect some of the high-energy particles that stream from the Sun. But outside Earth's magnetosphere, travelers are shielded only by what they bring with them. And the radiation levels can be deadly. As Dr. Joseph Sharp of NASA's Ames Research Center explains, "In 1956 there was a solar flare which, over the course of half an hour, would have subjected any astronaut to 1000 times the lethal dosage of radiation."

One simple way of shielding future settlers from potential solar radiation is to place much of the ship's bulk between them and the Sun. With this in mind, the transport ships are designed to have fuel tanks and other equipment on the sunward side, in front of the shuttles. Should a solar storm occur, the crew could also seek temporary refuge in the small but shielded Mars shuttles until radiation drops to a safe level.

The dangers of prolonged space flight are not entirely external. The human body itself has substantial difficulty



JPL/NASA photo

Chaotic terrain: flood source?

in coping with weightlessness. For example, muscle atrophy has long been recognized as a major problem in weightless situations. After just a few days of zero-G, there is a loss of muscle tone. Within months, muscles begin to deteriorate significantly. Fortunately, certain types of exercise have been found to minimize these negative effects on the human muscular system. Soviet cosmonauts, who often spend months aboard the Salyut space station, typically spend two to three hours exercising each day.

In addition to muscle atrophy, other physiological problems persist. The organs of the abdomen tend to drift up toward the chest cavity. The heart becomes enlarged and works less efficiently. But the greatest problems lie within the skeletal system. As Dr. Sharp explains, "Every six months we replace our skeletal system completely. Old bone tissue is dissolved and replaced with new." Bone tissue renewal takes place on the outside of each bone. In the center, old tissue is dissolved into the blood stream and excreted. The process is similar to the growth of rings in a tree, only in reverse.

Experiments done on Soviet bio-research satellites indicate that after only 11 days of weightlessness, the system which renews bone material shuts down completely. In itself, this might not be a problem, but the process of bone *absorption* seems to continue indefinitely. In effect, skeletons soon begin dissolving themselves in zero-G. After a six-month trip to a rugged and dangerous environment, no martian colonist can afford to arrive with weakened, brittle bones.

Taking these and other features into consideration, members of the Case for Mars conference decided that the Earth-Mars transport ship should spin to provide ⅓ Earth gravity — enough to keep the bone renewal mechanism working while also acclimating the colonists to the conditions they'll experience on Mars. Given the physiological, structural, and technological boundaries, the triaxial spacecraft design emerged as the most practical. Based on Shuttle and Space Station technology, the craft could be reusable and comparatively inexpensive.

. . . We've heard descriptions of it. We've seen photographs of its dusty surface. We have even gazed with expectation at its fuzzy image through Earth-based telescopes. But in the window of our twirling craft, day after day, Mars is only a bright star. Then one morning, we look out the viewport to discover a wonderful sight: that "star" has become a tiny orange ping-pong ball with glowing white poles. Slowly, its vague grey blemishes resolve into round spots, streaks, and valleys. Soon we see the Mars we have hoped for. The books, the photographs — even our imaginations — have not prepared us for the stunning reality outside the viewport. Now it's time to leave our home of the past six months and go to our new home, the New World.

After journeying half a year, the excited passengers climb into the three Mars shuttle craft. They are not conventional astronauts, or even scientists necessarily. They're members of the business sector — experts in mining or industry — and working class people who will form an integral part of martian society, just as they did on Earth.

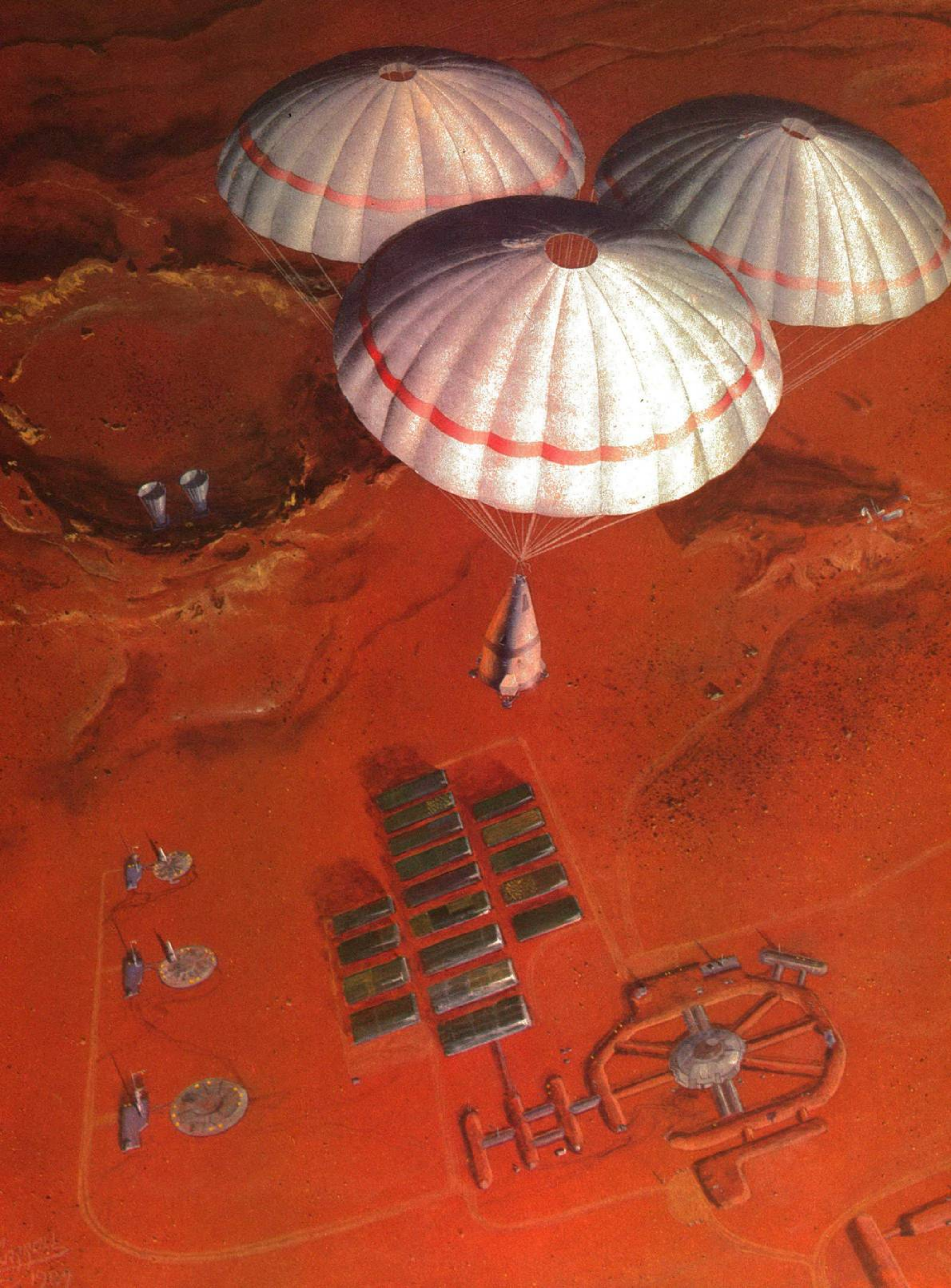
While the landing craft drop away from the transport, three more shuttles (left by the last transport flight) are lifting off from the martian surface to rendezvous with the now-empty transport ship. They will dock on the vacant cradles for the return portion of the spacecraft's orbit. One fact alone enables this procedure to take place: fuel for the Mars shuttles is manufactured on the surface of Mars itself.

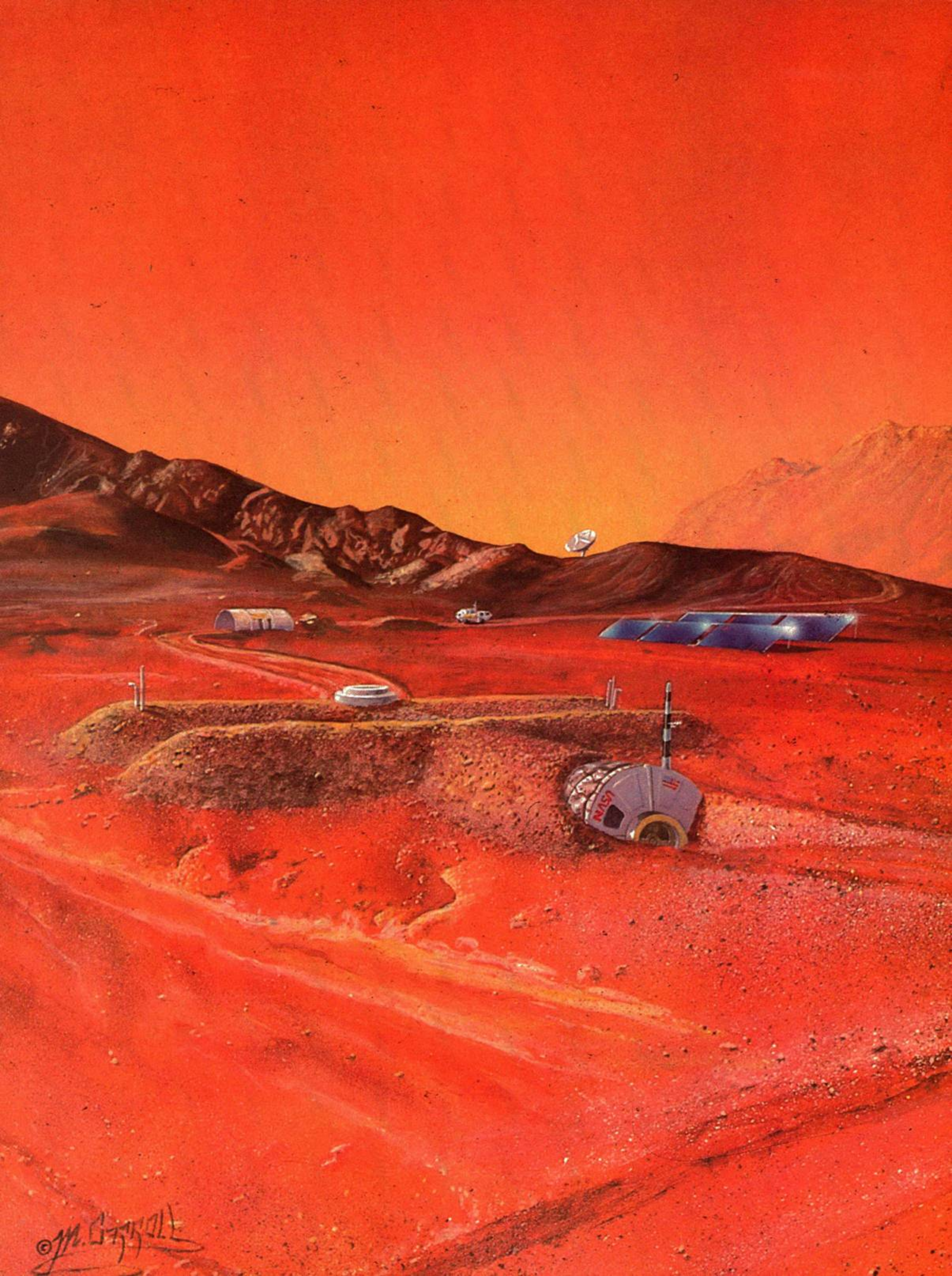
According to James French, an engineer at NASA/JPL and vice-president of the World Space Foundation, several different fuels can be obtained from the martian environment. Unfortunately, most of these involve hydrogen, which must be extracted by electrolyzing water — a scarce commodity on Mars. Since water is difficult to cull from the martian atmosphere or surface, French suggests another fuel: carbon monoxide oxidized by liquid oxygen. "It's not as efficient as some other fuels, but it doesn't require water to make it."

According to French, 100 to 150 kilowatts of electrical power would be needed to run a propellant plant. Solar

The last of this trip's shuttle craft descends toward its landing pad, while the half-buried buildings of the Mars base sprawl below. The dark structures are greenhouses and a solar power "farm." Living quarters occupy the almost-complete ring, the glass bubble in its center houses recreation facilities and a mini-park, and laboratories and factories lie between the greenhouses and the living quarters. In the crater (upper left) are the cooling towers of the nuclear power plant.

Overleaf: From ground level, the base appears deceptively small since most of the structures are wholly or partially buried to escape the climatic extremes of the martian seasons. The structures themselves derive from modules developed for NASA's Space Station, back in the 1990s, and ferried here by expendable rockets.





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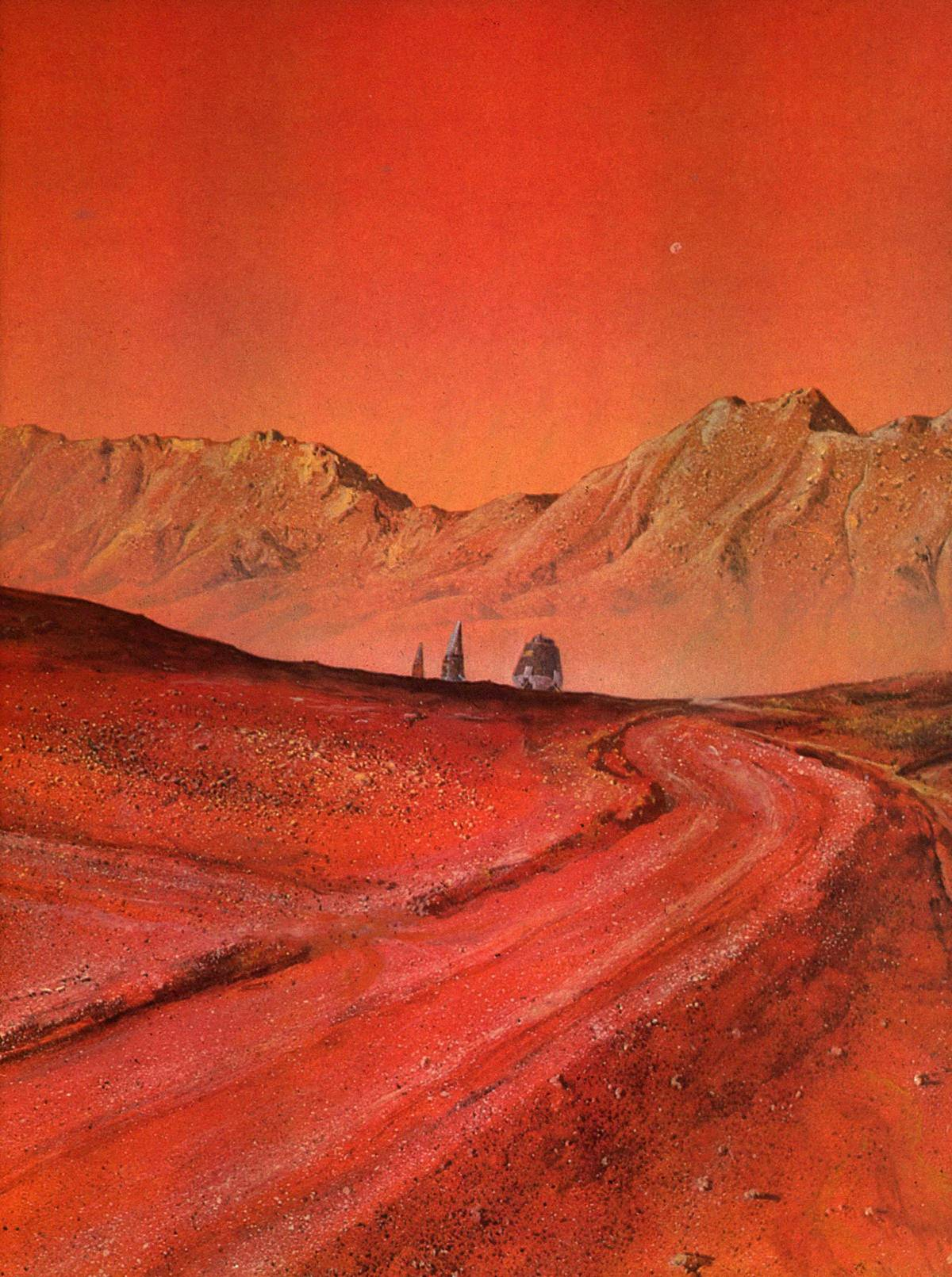

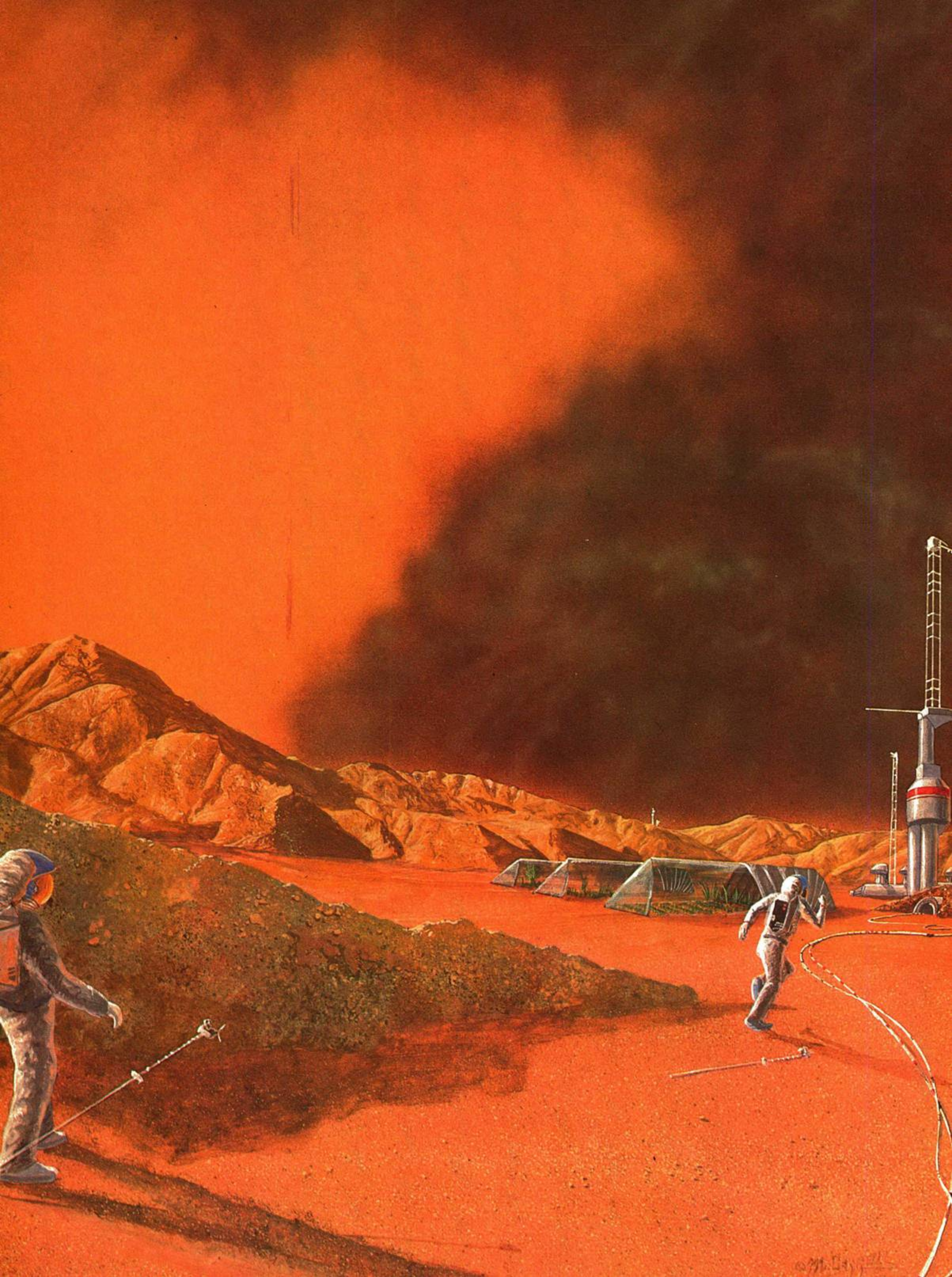
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cells take up an inordinate amount of room and are much less efficient than a small nuclear power source — moreover, sunlight at Mars averages only 43% as strong as at Earth. The actual best choice for a power source is hard to pick at this stage. In any case, the propellant-extraction plant would be completely automated, slowly synthesizing fuel during the months between launches. As the three craft take off to rendezvous with the incoming transport ship from Earth, the fuel plant would begin production immediately for the next wave of explorers.

Having left behind a dozen passengers on a world of great promise and re-embarked the shuttles filled with mail from the base, the interplanetary transport ship sails on through the dark skies of space back to Earth.

Mars. Planet of deserts. A vast wilderness of drifting sands, broken rock scoured by the wind, mist-filled valleys, lofty volcanoes, and snowy polar ice fields. A world whose peach skies are streaked by white wisps of cirrus cloud and thunderous dust storms. There are multitudes of reasons for going to Mars. It is the most Earth-like of all the other planets in our solar system. Its weather, geological processes, and ancient history can provide clues about the natural forces at work on Earth, which will have a direct bearing on our everyday life.

The Red Planet offers resources, not only to support colonies, but perhaps also to enhance and supplement Earth resources. According to Bruce Cordell, an authority on manned Mars exploration, "The discovery of significant ore deposits on Mars would . . . provide an economic stimulus to explore and establish numerous manned settlements." Cordell says that the processes responsible for making ore deposits on Earth are poorly understood as yet. It is evident, however, that certain geochemical, volcanic, and water-related processes are important — and these processes were also apparently present on Mars at some time. Ore deposits may well turn out to be a major factor in selecting sites for martian settlement. Other governing factors will include weather and topography. A permanent settlement requires an area with solid rocky ground, as opposed to sand or unstable avalanche areas near the walls of craters and canyons. Also desirable are areas with less wind and milder temperatures — in short, a more genial climate.

Communications also demands consideration in selecting a permanent site. As exploration of Mars advances, direct communication with Earth will be needed for long periods, despite the (average) 20 minutes it takes for a radio signal to leave Mars, reach Earth, and return with a reply. Sites in rugged terrain or at high latitudes will have radio communications with Earth for shortened periods, since the home planet will be out of sight part of the time. For this reason, "areostationary" satellites will be placed in orbit above Mars. Like Earth's geostationary weather and communication satellites, a network of these spacecraft will englobe Mars so that communications to and from Earth can be sent or received at any time.

Somewhat surprisingly, subsurface water may not be an important factor in selecting a colony site. Some researchers feel it is much easier to obtain water from the dry martian atmosphere than from subsurface permafrost. There is much evidence for the presence of near-surface ice, however. This includes lobate debris aprons, rampart craters, collapsed and pitted terrain, and patterned surfaces. Near-surface ice is probably similar to permafrost, which is quite difficult to extract. In arctic regions on Earth, it is notorious for destroying drill bits. Additionally, martian permafrost may not be very pure. According to Ben Clark of Martin Marietta Corporation, Viking data indicate that subsurface water may be "something akin to Dead Sea water — a highly viscous 'soup' laden with lots of dissolved salts."

Nevertheless, obtaining water from the atmosphere will be difficult. Water vapor varies according to location and season, but averages a scant 0.03%. If water extractors worked full time, enough could be provided for the colony's needs — especially if water were scavenged from all the colony's waste products and purified. One thing is certain: water cannot be brought in significant quantities from home. Clark points out that it costs approximately $15,000,000 to get a ton of anything to Mars. "You could put a swimming pool on Mars, but it would cost you billions of dollars to fill it." Ultimately, water will be the most treasured possession of martian cities.

The Case for Mars

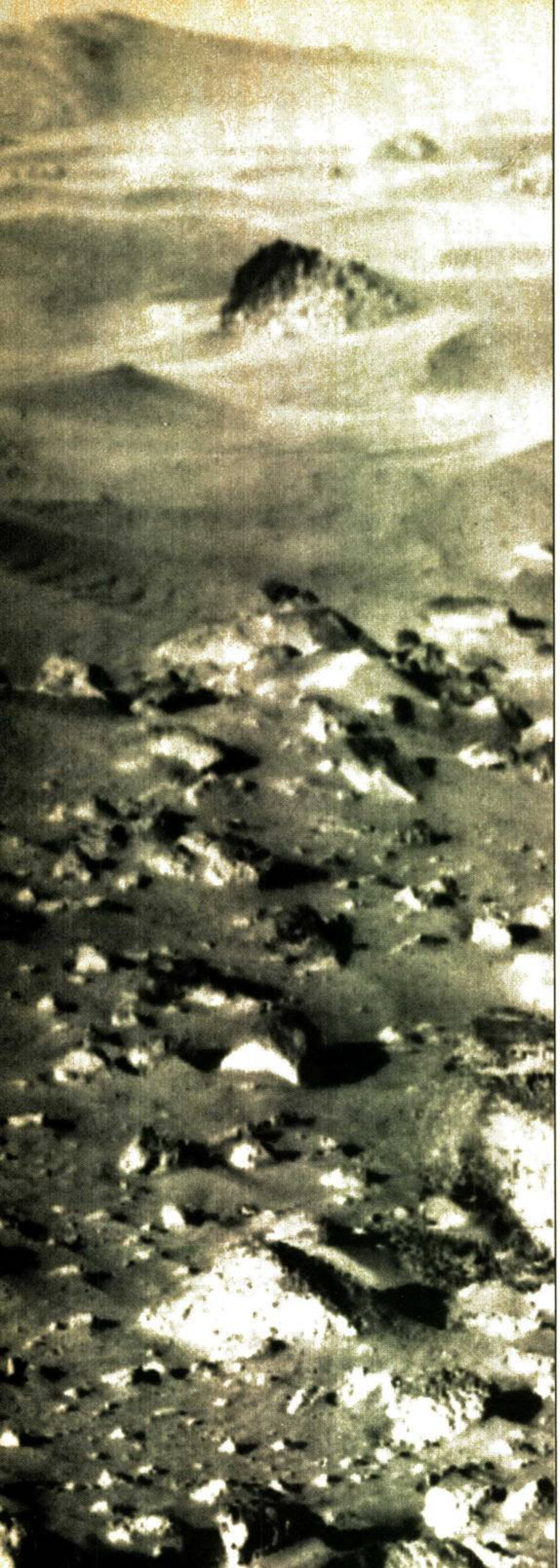
Since 1971, there has been a marked lack of NASA studies on the subject of manned exploration of Mars. For many years after the Apollo successes, the topic of Mars flights was in effect taboo at the agency and in the space exploration community at large. The feeling was that the nation's political atmosphere was at best indifferent — and often actively hostile — to any new project of that magnitude. Nevertheless, many engineering and research firms around the country have been doing work on other projects which directly relate to manned Mars exploration.

In 1978, Chris McKay, a Ph.D. candidate in astrogeophysics at the University of Colorado at Boulder, began a series of informal seminars called "The Habitability of Mars." He was joined by fellow students Carol Stoker and Penelope Boston, as well as computer scientist Steve Welch and Tom Meyer, president of a local engineering company. This group decided to turn their seminars into a formal conference, inviting people who were experts in the fields of Viking spacecraft results, propulsion, psychology, materials processing, physiology, etc. Word of the conference spread and people from a surprisingly wide number of disciplines attended the first Case for Mars conference in April and May 1981. They soon dubbed themselves the "Mars Underground."

The conference tried to "design a blueprint for the exploration and settlement of Mars," while helping to establish a direction for space technology over the next three decades. In July 1984, a second conference — "The Case for Mars II" — was held.

As one colonist turns and sprints for cover, another stands transfixed by the approach of a giant dust storm. On occasion, the entire planet can be girdled by a single "mega-storm" that hides the surface from view for weeks on end. Designed to be almost entirely self-sufficient, the base must be prepared to batten the hatches on a moment's notice and ride out the worst that Mars has to offer.

. . . Our descent through the martian atmosphere is controlled aerodynamically; our shuttle has a bi-conical "lifting body" design. At 19,000 feet, three giant parachutes deploy. As we drift through a few wisps of ice crystals, the martian colony sprawls beneath us. Symmetrical mounds of soil mask an immense grid of underground habitats. These living, working, and research



areas are built from modules based upon old Space Station technology.

Beyond an eroded crater rim stand several cooling towers for the nuclear generators which power the colony. These are supplemented by solar panels closer to the colony. Rows of greenhouses make a distinct contrast on the red plains. To support the needs of 15 people, the greenhouses have an area equal to about six football fields. On a nearby bluff we see communications centers, high-gain antennae, and weather stations.

At 4600 feet, our parachutes are jettisoned. Retro-rockets and thruster jets carry us to the landing area where our two sister ships have already arrived . . . .

Most of the colony will consist of habitat modules, with living quarters that are fairly spacious, comfortable, and space-efficient. Large recreation areas will also be constructed. Tennis and raquetball courts, a shopping mall, and even a large recreational greenhouse will give the colony environmental variety — necessary for morale and psychological health.

But the greatest playground is, of course, Mars itself. Spectacular vistas will await the colonists, and major technological advances will render exploration more comfortable than in the past. Sealed rover vehicles will be pressurized to a shirt-sleeve environment. Hazardous work and research can be carried out — at least partially — by remote-controlled or automated robot craft. Perhaps the most significant technological advances will be made in pressure suits. The suits of the post-Apollo and Shuttle eras are pressurized to an extent that renders them too inflexible for a ⅓-G environment. Strides in suit technology will allow much greater flexibility, and skin-tight suits may also be an option.

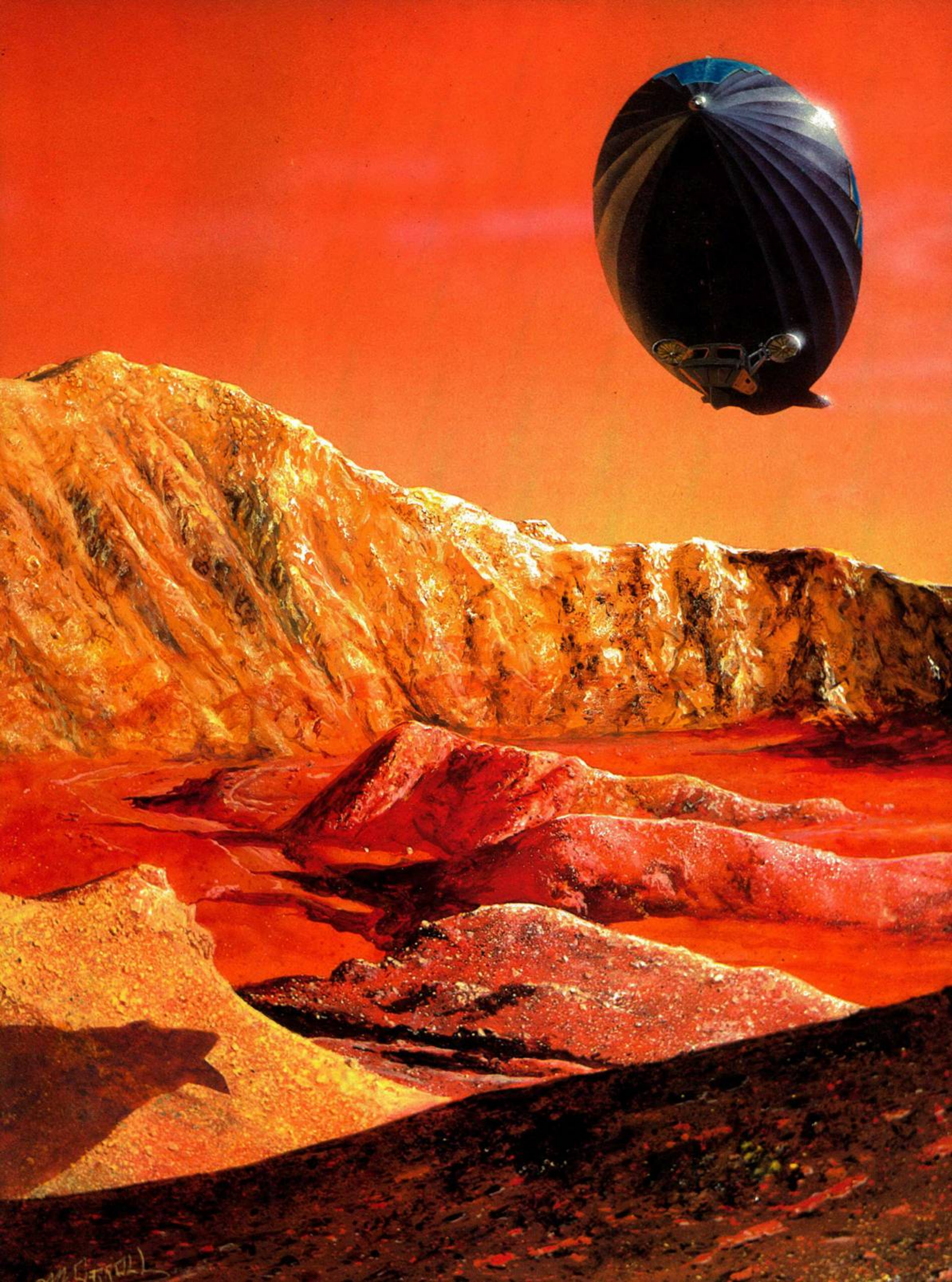
Long-distance exploration is a challenging engineering problem, with several approaches being pursued. Roving surface vehicles are a natural first step. These vehicles are ideal for close and mid-range transportation, especially across regions where the terrain holds no surprises. But for long-range exploration, a higher vantage point is sometimes needed.

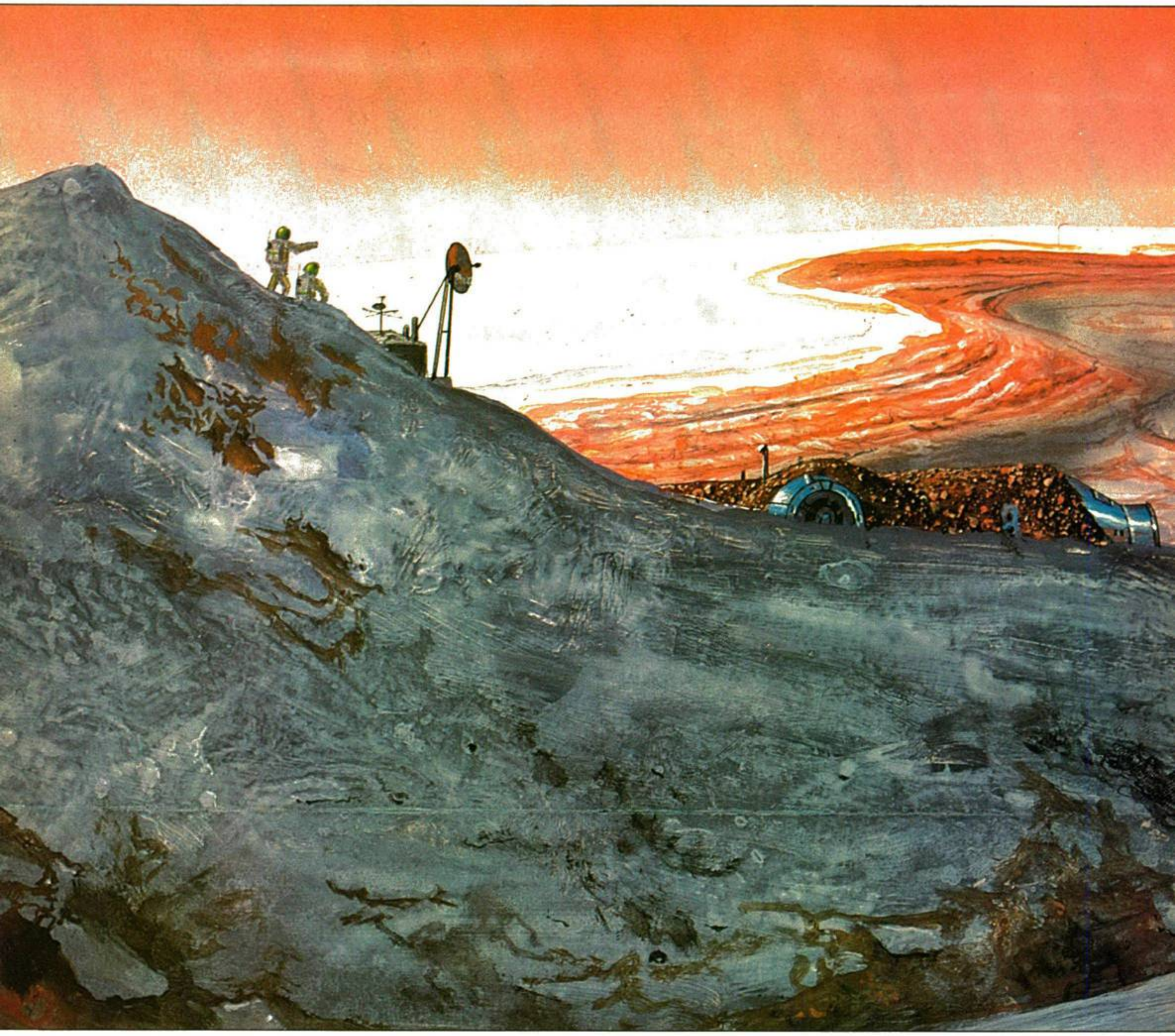
Brian O'Leary of Science Applications, Inc., in conjunction with space scientist S. Fred Singer, makes a strong case for a survey base on either Phobos or Deimos, Mars' two moons. In addition to affording an exciting scientific study of the two asteroid-like bodies, these bases could serve as weather observation stations, communication centers between exploratory parties, and stations for operating remotely-controlled vehicles over almost the entire globe of Mars.

Aerial reconnaissance will be of utmost importance to researchers, too. From a simple transportation standpoint, travel by air will be as efficient on Mars as it is on Earth. With materials derived from terrestrial ultra-

Long-range prospecting and exploration on Mars calls for vehicles more versatile than wheeled rovers. Here, a hydrogen-filled dirigible glides above rugged terrain. Solar cells on its upper surface augment the electric power supply to its motors.

Overleaf left: The martian reality is powder-fine dust, broken rock, and gravel scoured by a thin atmosphere of carbon dioxide. Yet in the polar ice caps, and in a probable layer of permafrost below the surface, lies enough water to permit humans to establish a colony on Mars. JPL/NASA photo.

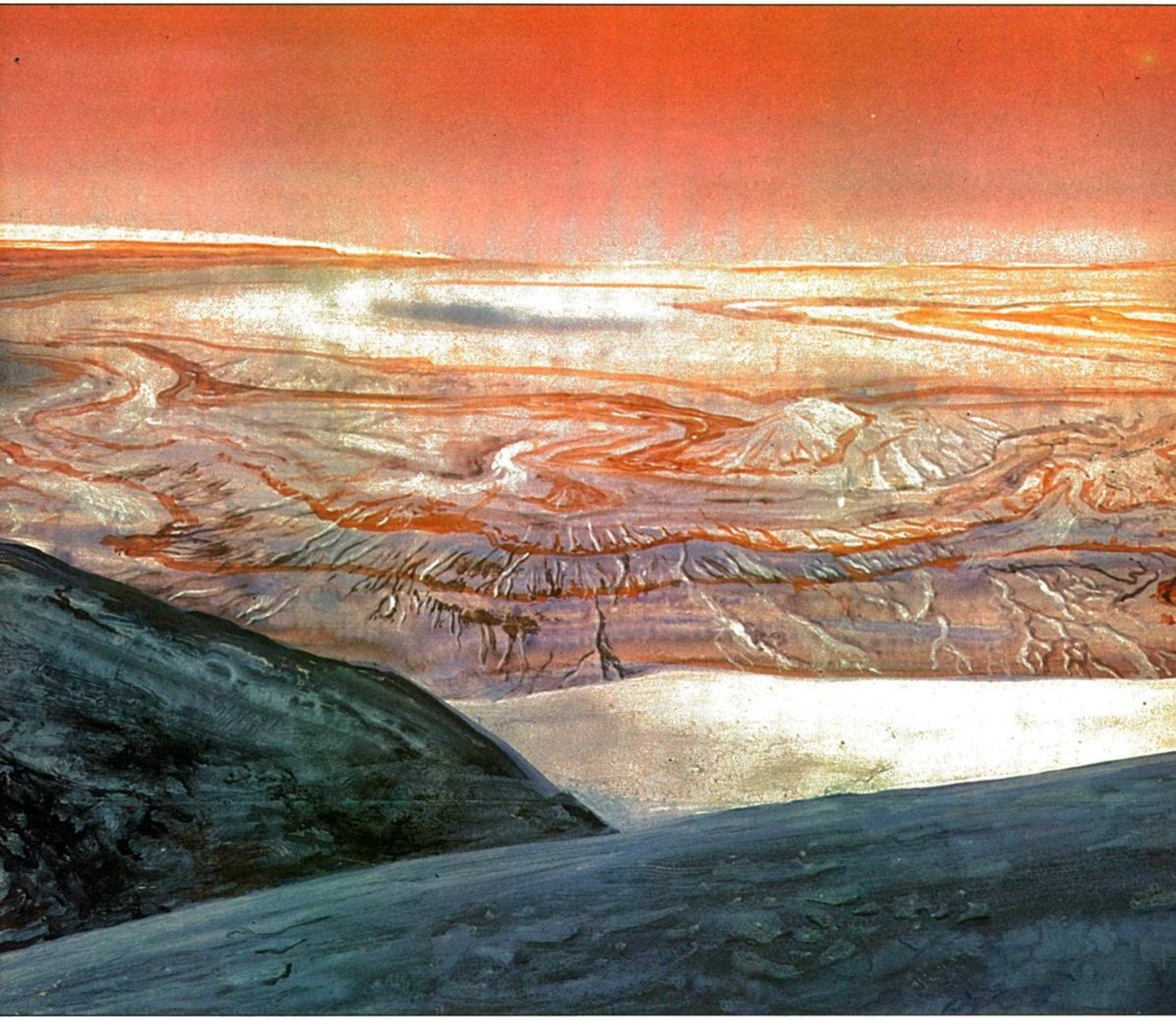




light airplane technology, Mars planes will be quite practical, employing small hydrazine engines to propel long-winged craft over ranges of several hundred miles. Since the thin martian air calls for large areas of wing, aircraft may carry lightweight solar cells on their wings' upper surfaces to power small engines underneath.

But Mitchell Klapp of MIT suggests another mode of air transportation: the dirigible. Filled with hydrogen gleaned from martian water, solar heat would add to the craft's buoyancy in the low-pressure environment. The top of the dirigible would be covered with solar cells to power systems inside the small manned gondola as well as the large fan engines which move the aircraft. These ships would not move quickly, but would be simple to operate and excellent for moving loads in and out of rough places.

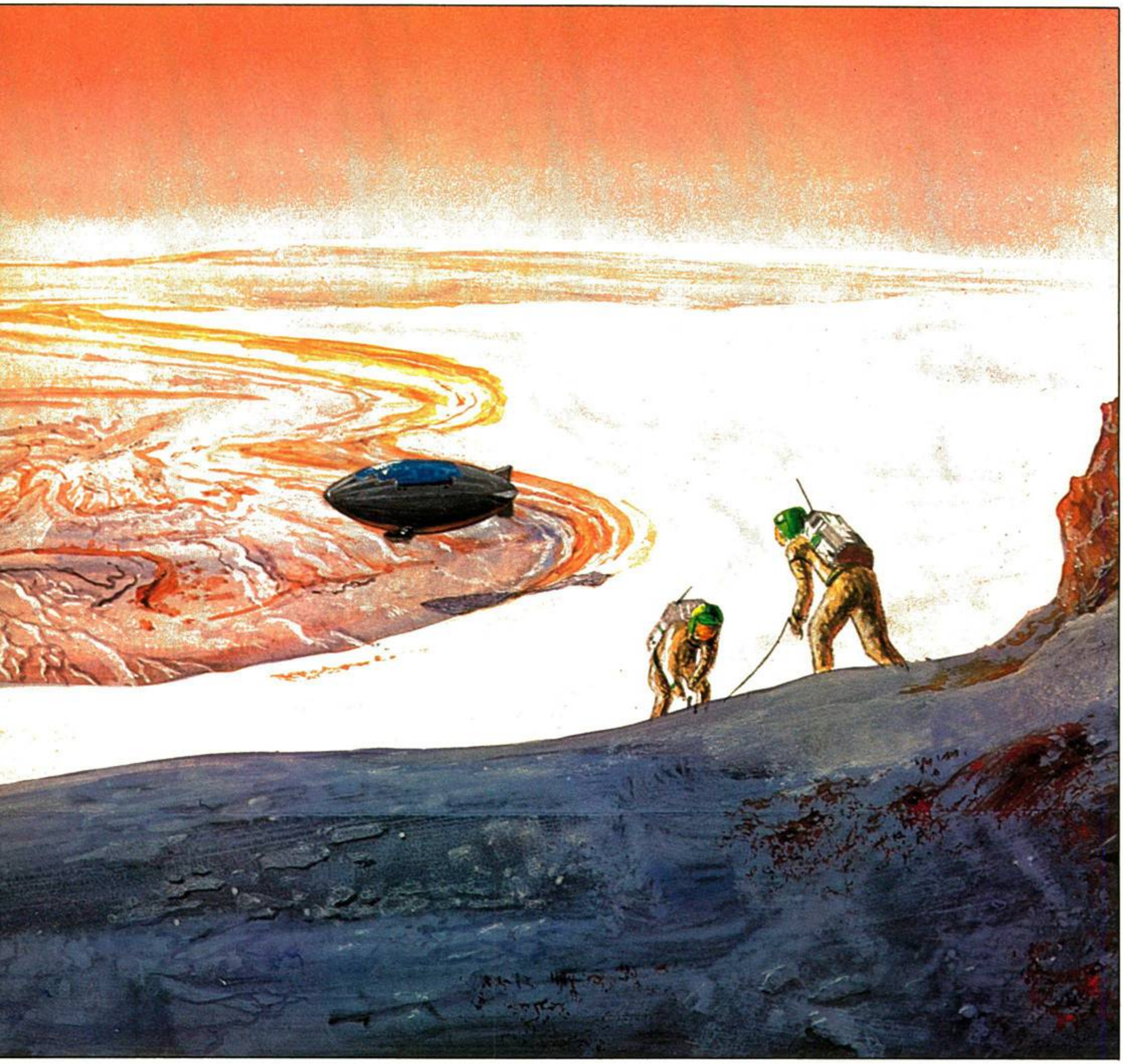
The martian colony's permanent location may not be in one of the most scientifically-interesting areas of the Red Planet — nor does it have to be. With these transportation vehicles, researchers, explorers, and colonists alike will have access to nearly any location on the surface of Mars. The new Martians will venture into the volcanic wilderness of Elysium or the magnificent Tharsis bulge. They'll perch on the edge of the great canyons at Noctis Labyrinthus to watch the morning fog



float away. They'll see the ochre dunes of Hesperia and stand on the brilliant ice of a polar canyon. These people will be on Mars for practical reasons: business, mining, research. But at these awesome places, they may perhaps feel a deeper, more important reason for being here on another world far from home.

After hours and hours of flying over dark sand, our dirigible clears the last of the massive polar dunes and we are greeted by a blinding flash of snow. Beyond lies the gently sloping, layered terrain of the north polar cap. Thousands of layers of alternating dust and ice bear witness to climatic changes eons past. By studying these layers, scientists may be able to piece together a history of the Sun's energy output and how it affected the martian ice ages. This information may in turn unlock secrets to the Earth's own periods of glaciation.

These pages and overleaf: A survey crew explores a landscape near the edge of the south polar cap. A small ground station antenna (left) keeps the team in contact with the base via a network of "areostationary" satellites. By understanding the glacial epochs on Mars, we may understand better what drives these climatic extremes on Earth.

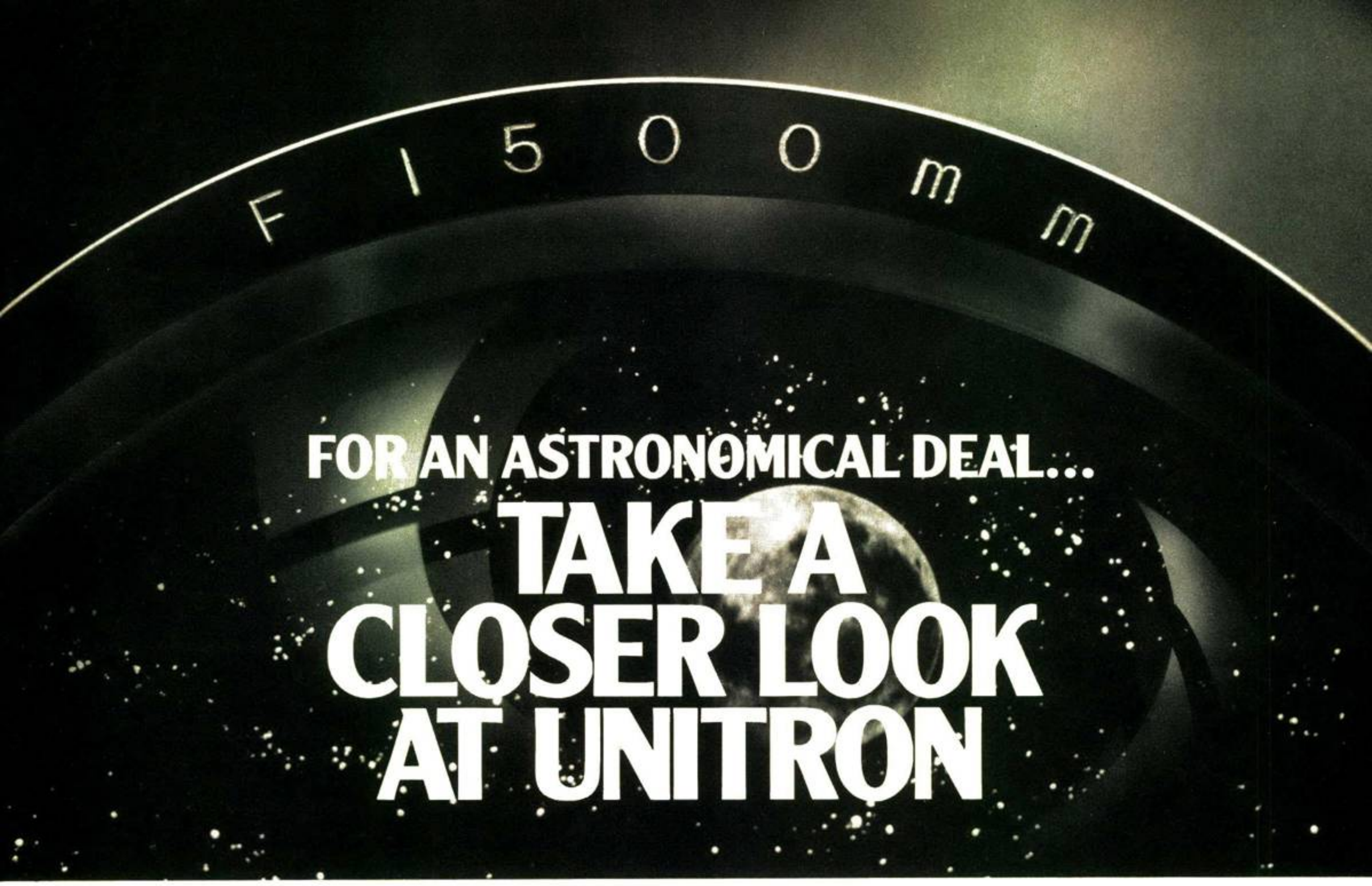


Courtesy of Reuben H. Fleet Space Theater

There is much to be learned here. But for now, we relax and forget about science, economy, or business, and simply enjoy this spectacular world which is now our home.

In the 1950s, *Collier's* magazine published the now-classic article "Can We Get To Mars?" by Werner von Braun and Cornelius Ryan. Though some of its concepts have become obsolete, the article captures a feeling of wonder and expectation. Today, we are drawing up other scenarios; they, too, will be superseded as designs, technologies, and ideas fall prey to future advances. No matter. Although the Case for Mars is drafting blueprints, this isn't where its real importance lies. Rather, what counts is the attempt to glimpse the challenges and adventures awaiting those who have the privilege — and courage — to live, work, and play on the rusted sands of a new world.

Michael Carroll is a space artist and freelance writer who lives in San Diego. His paintings have often appeared in ASTRONOMY, and his last article was "A New Mission to Saturn" in the December 1983 issue. Carroll writes: "I'd like to dedicate this article to Chesley Bonestell, whose paintings of Mars and other parts of the universe have inspired many an astronomical artist, including myself."



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Observing May's Annular Eclipse From Tamaulipas, Mexico

"On vacation?" the children called out as they rode their bicycles past me down the avenue. I waved and answered "eclipse" in Spanish. As the only blond-haired man seated in the plaza that evening in Ciudad Victoria, Mexico, I was an obvious target for young Mexicans who were eager to practice their English. Four others from New Mexico State University and I were here on a vacation of sorts: an expedition to view the annular eclipse of May 30, 1984.

Lured by the rarity of the event and the ease of driving to it, we had traveled first to Brownsville, Texas, and then 300 kilometers south into the state of Tamaulipas, Mexico. A day earlier, in Corpus Christi, Texas, we had assessed the weather. A meandering cloud front on the satellite map indicated that Ciudad Victoria, the capital of Tamaulipas, was the best shot because of its location (a line drawn perpendicularly on the map from our home in Las Cruces, New Mexico to the eclipse path intersected the path very near Ciudad Victoria) and the statistical likelihood of clear skies. Now, as we sat in the plaza and looked up at a uniformly overcast sky, we questioned our choice.

A newspaper reporter, guessing our intent, inquired where we wanted to watch the eclipse. Our destination, we told him, was a small square on the map named La Jolla Verde.

The next day, the 29th, we devoted to locating the site. Our goal was to fix an exact position for astrometric purposes. Navigation out of the city was hampered by traffic and the fact that we could not use the Sun for direction. Ciudad Victoria lies 30 km north of the Tropic of Cancer. As we were less than a month from the summer solstice, the Sun was nearly overhead. So whenever sunlight did emerge from holes in the clouds, no shadows appeared — a weird sight to people raised in temperate latitudes.

We finally managed to get outside the city limits. La Jolla Verde was only 25 km away as the crow flies, but a steeply ascending, winding road strung out the trip to the point where we were sure we had missed it. We stopped at a remote hacienda and asked a startled housewife for directions. She pointed to a descending side road that appeared fit only for goats. After nearly half an hour, we spotted a single casa several kilometers below us in a narrow canyon. Even if we had succeeded in lugging our equipment down to (and up from) this site, our view of the morning Sun would have been obstructed by the canyon walls!

After returning to our vehicle, we realized what many an eclipse-adventurer undoubtedly had before us: the ideal eclipse-watching site is more easily reached by compass and ruler than by way of tennis shoes. We raced down the mountains just ahead of a rain shower. Tendrils of clouds threatened to engulf us at every switchback, and by the time we returned to Ciudad Victoria it was pouring.

By now, a few other Americans had appeared in our hotel. They had also aimed their vacations at this unlikely locale to take in the eclipse. Inevitably, the conversation drifted to that universal subject among astronomers: the weather. We resigned ourselves to an attitude of "eat, drink, and be merry, for tomorrow it may be cloudy."

The day we had been waiting for dawned drizzily. As soon as the sky could be seen, though, it appeared lighter to the north. We set up in the town of Jimenez, 100 km from Victoria. Jimenez was well situated in the eclipse path and the town plaza made an excellent landmark which could later be fixed precisely. Above us, two layers of clouds — a high one moving south and a low one moving north — made predictions difficult. A "sucker hole" of blue to the north tempted us. But the plaza clock chimed out the hour before eclipse maximum, so we decided to deploy our equipment and take what we could get.

As the partial umbral phase began, we could see the Sun momentarily from time to time. These glimpses occurred more and more frequently as the Sun waned. People began to mill about the plaza. Some watched us; others watched the eclipse. A local radio station had set up a remote site down the street and was providing passersby with welder's masks and pin-hole projection boxes with which to view the event. We later learned that this was part of a nationwide network set up along the path from Guadalajara to the Gulf of Mexico, formed by radio stations to report firsthand on the eclipse.

The crescent Sun could be seen through the thinning layers of clouds as annularity approached. The image would occasionally "blow up" and then become sharp again as the clouds varied in density — much as an image in a telescope reacts to wildly fluctuating seeing. By now, the sky had become darker. The air was also noticeably cooler.

With only minutes to go, my companions manned their shutters. During annularity, a situation occurred which we had not foreseen: we could see the eclipse — and the image remained steady — but it was heavily filtered by intervening clouds.

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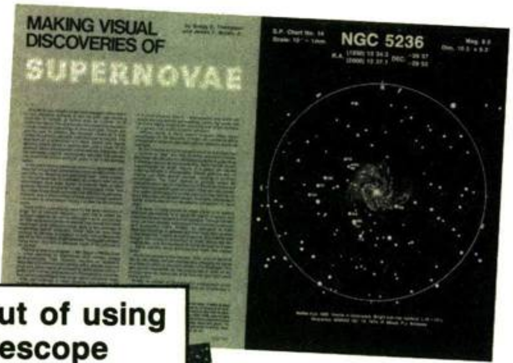
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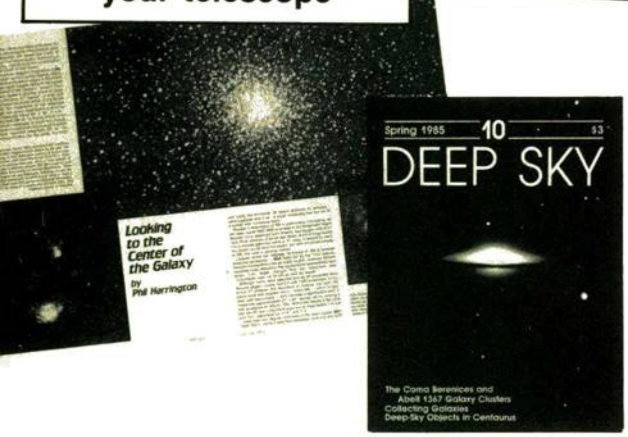
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Calculated exposure times and filter combinations were thrown out as we hastily tried new settings.

I had planned to take a motion picture of the annular phase with a time-signal sound track. While my camera was operating, I had an opportunity to observe the event visually. The annulus was complete and broad. The clouds colored it a silvery white. It looked like one of the silver wedding bands worn by my colleagues, Kazuhiro and Keiko Sekiguchi, transplanted into the sky. The unfamiliarity of the ring shape in nature made it seem incongruous, and brought to mind the sort of fantasy panorama painted to illustrate the view of another world in a science fiction movie.

After third contact, we heaved a collective sigh, the anticipation over. As we relaxed to watch the rest of the partial eclipse, the clouds broke and gave us a clear view of the sky.

Mexico is fascinating in its own right, but we eclipse watchers had the added advantage of instant rapport with people scattered along the eclipse path. Communications and customs problems diminished with the words "el eclipse." The event is a cultural as well as visual experience unique only in astronomy. In assessing my own experiences, I offer the words of Steven Berrick, another member of our group on his first eclipse expedition: "Okay, were's the next one?"

Thomas Hockey
New Mexico State University
Las Cruces, NM

The Rise and Fall of the X-20 Dyna Soar

Imagine, if you will, a space shuttle. Not *the* Space Shuttle, but *a* space shuttle.

It is small: a mere 38 feet long with a wing span of 22 feet — smaller than the X-15 rocket plane that preceded it, but larger than either the Mercury or Gemini spacecraft. This shuttle's bottom skin panels are coated dead black to radiate the heat of re-entry. The windshield remains covered until after re-entry when the cover is ejected, allowing the pilot to see the runway on which his shuttle will set down by means of landing skids.

This shuttle is the X-20 Dyna Soar, an early Air Force man-in-space project which could have been the United States' first manned spacecraft. Instead, it was cancelled in 1963 with the first flight vehicle uncompleted and a B-52 bomber only partially modified for drop tests.

What happened?

According to William Lamar, director of X-20 engineering, Air Force interest in hypersonic gliding was originally motivated by the need for a long-range bomber. Before air-to-air refueling was demonstrated, the Air Force hoped to achieve intercontinental distances by means of high-velocity rocket boost followed by a hypersonic glide over the target and normal landing.

Feasibility studies began as early as 1954 and continued until Dyna Soar development was confirmed in November 1957 — a month after the Soviet Union embarrassed the United States with the launch of Sputnik 1. Several declassified internal letters written in early 1958 emphasize Air Force interest in getting a man into orbit as soon as technically possible — but show much uncertainty on the best way to accomplish this.

Should they simply accelerate Dyna Soar development? Or would it be faster to develop a ballistic spacecraft, since "the problems associated with a manned orbital flight . . . outside the sensible atmosphere . . . may posit less stringent design requirements than the lower altitude, hypersonic Dyna Soar-1 flight profile." Another alternative was to build Dyna Soar, but use it as a semi-ballistic spacecraft and worry about its hypersonic glide performance later. This would achieve the goal of early orbital flight, and also provide a vehicle which could later be developed into a flexible space shuttle.

In October 1958, the newly-organized National Aeronautics and Space Administration — basking in President Eisenhower's preference for civilian space programs — formally began Project Mercury. This determined that the United States' first manned space flight would use a ballistic vehicle — a decision which also determined the course of United States space flight through the Apollo program to the beginning of today's Space Shuttle.

But the Air Force was not finished with Dyna Soar. There was still the matter of hypersonic flight, which the service saw as necessary to any militarily-useful manned spacecraft. Dyna Soar became a strictly research-and-development project, but the cost — $800 million — was considered by some to be very expensive for a project that would not lead directly to a weapons system.

In 1961, shortly after the first manned spaceflight by Soviet Air Force Lieutenant Yuri Gagarin, the U.S. Air Force agreed to a Boeing proposal called "Project Streamline." In the words of the official press release, the Air Force eliminated "all suborbital flights employing the Titan-II as a booster. The development program will move directly from manned drops of the Dyna Soar glider from a B-52 to orbital flight which will require an improved booster . . . based on Titan-II technology . . . [with] large solid propellant rocket motors as the first stage."

Thus was born the Titan-III, which has since become the military's all-purpose utility booster. The Saturn I was also considered and Lamar still believes that would have been the best launcher to use, since the Saturn was by then a proven vehicle and its greater power could have removed some of the weight constraints on Dyna Soar. However, some factions in the Air Force wanted their own booster and used Dyna Soar to justify the Titan-III — the single surviving element of the Dyna Soar project.

Renamed the X-20 to emphasize its experimental nature, the project limped along. By 1963, the cost had risen to $1 billion, largely because of Titan-III development costs. Then, in December 1963, Defense Secretary Robert McNamara cancelled the program. Dyna Soar was replaced by the Manned Orbiting Laboratory, a space station program which used Project Gemini technology — and which was also subsequently cancelled. To date, despite billions spent and obvious Air Force desire, no purely military manned spacecraft has flown.

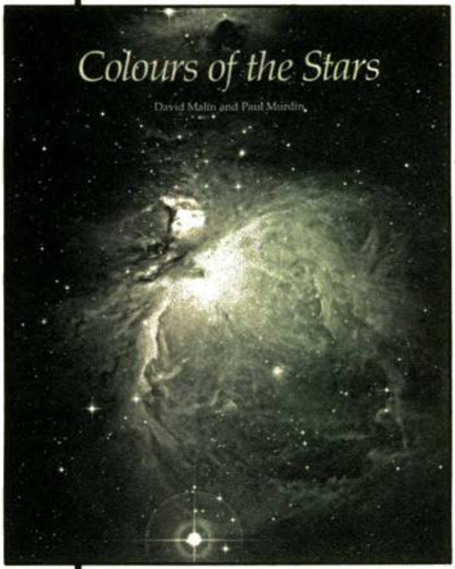
Why was Dyna Soar cancelled? Even today, there is no agreement. Curtis Peebles, writing on early Shuttle development, noted that the airframe was too limited in size and capacity for useful work. As a result, Peebles says, Dyna Soar was delayed to the point of obsolescence. Lamar emphatically disagrees, stating that even today Dyna Soar would be at the very peak of technology: "It is ballistic vehicles that are out of date." Lamar further suggests the familiar "manned versus unmanned" arguments within NASA also took place in the Department of Defense and that some people wanted proof of man's usefulness in space before spending the money to fly a man and find out.

Lamar believes the X-20 should have flown despite all this. The original spacecraft could have carried up to 1000 pounds of instrumentation or payload and as many as four people. (The cabin would have had about as much room as a Volkswagen "Beetle.") In addition, the expendable interstage or "trailer" which rode up into orbit contained about 1000 cubic feet and might have functioned much as the payload bay on today's Shuttle.

More importantly, this early shuttle would have been the first of three generations of gradually-improving, winged spacecraft. These could have

Colours of the Stars

by David Malin & Paul Murdin



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led to something resembling the modern Space Shuttle far earlier and at less cost. Research on the early models would have improved later versions, resulting in a more capable and flexible Space Shuttle today. Lamar points out that both people and technology — for instance, the carbon material used on the Space Shuttle's nose and wing leading edges — were adapted from the X-20 program for use on the Space Shuttle.

In the meantime, we would have had those early shuttles to gain space flight experience — with spacecraft far more capable than the ballistic spacecraft NASA developed. The jobs which the original Dyna Soar was intended for are still largely classified, but Lamar suggests that "anything you can think of, probably was." He goes on to mention the substantial payload the "trailer" might have carried, and such scientific applications as a manned telescope platform. Other writers have suggested such varied applications as space station resupply, orbital command post and global surveillance, single orbit reconnaissance, and even bombing from space — probably less efficient than ballistic missiles, but not at all impractical according to Lamar.

It is interesting to note that the Air Force has now let contracts for studies on a number of small space shuttle configurations. All of these have at least one thing in common: in size and capability, they look remarkably like that 25-year-old design — the X-20 Dyna Soar.

Donald F. Robertson
Sacramento, CA

Kids and Astronomy

It happened again last month . . . at a party. The topic turned to hobbies and I announced an affinity for the study and practice of astronomy.

"Oh, and what sign are you?" asked an otherwise bright young woman. We all know the rejoinder: "That's AstroNOMY. Real science, not myth. Let me show you some photos . . . ."

Adults are encumbered with pounds of pseudo-intellectual baggage concerning astronomy. Like the computer revolution, it exploded into a full grown science after they graduated from public school — those institutions where each generation accumulates most of the academic knowledge and instincts that will guide them for the next 50 years. It's human nature to become intellectually petrified by the age of 25 or so — to reject the challenges of new concepts like the Big Bang. Cosmic evolution and micro chips are best left to "the next generation."

And that next generation is doing just fine, thank you. My third-grade son recently invited me to his class as a guest speaker on astronomy, a topic his class was currently studying. Their big-print text contained factual information that was merely speculation in the college classrooms of the 1960s. These kids were smart, and if *you* ever have to undergo a similar inquisition — be prepared.

I began by announcing that the Sun is merely a star, made large by its nearness to Earth. This seemed to startle but one young girl, whose mouth gaped as she analyzed the news, found it logical, and then raised her hand.

"How far away is it?" she asked. My answer led us to the concept of the light-year for measuring distances to other stars. They still seemed unruffled. One boy even had a slippery grasp on the idea that travel near the speed of light would make your brothers and sisters back home grow up more quickly, which he thought might be fun.

"The Sun," I continued, "is one of many stars in our Galaxy."

"That's a lot of stars all together," a blond boy added. By now, more than half of the kids had their hands in the air.

"Right," I confirmed, "and here are some pictures of other galaxies . . . "

"That's the Andromeda Galaxy," offered a red-haired girl.

"Correct. It is more than two million light-years away."

They seemed willing and able to accept such a distance, even in our own small neighborhood of space. We turned to the planets.

"Venus is very hot . . . "

". . . and cloudy," added a blond-haired boy.

"And Jupiter is made of the same kind of gas that makes the Sun burn." They seemed briefly stuck.

"Could I walk on Jupiter?" asked a tawny boy named Phoung.

"Not really. You would sink in, and gravity might . . ."

"— smash you flat!"

"Right."

"What are the rings of Saturn made of?"

"They took pictures of it from a spaceship, didn't they?"

"And this time there were no men on it . . . just a computer, like we use in math lab."

They paused for breath while I explained the Sun's eventual fate. "It will one day grow old and fat," I told them, "gobbling up the inner planets."

"But we'll be gone by then," the red-haired girl suggested somewhat hopefully. "Like, we could move to some other place like Mars, couldn't we?"

This seemed to concern several of the kids, who wondered if they could take along puppies and grandparents and other treasures. I assured them they could.

Mars proved particularly interesting, and there was some passing speculation about life on the Red Planet until the blond boy recalled that "Viking 1 and 2 didn't find any." So much for that.

Men on Mars led us to a discussion of SETI, which was finally something new to the kids. Surprisingly, there was no mention of *Star Wars* or *E.T.* It seems third graders are able to more effectively divorce fantasy from fact than their supposedly wiser elders.

Forty-five minutes into the two-way "lecture," there were still 18 hands in the air, and comments and questions interspersed by gasps of wonder whenever I used a photo from *Galaxies* to illustrate a point. Then it was time to stop: the kids were due in math lab. There, computers were teaching them the multiplication tables in a three-week session that took Mrs. Melott, my third-grade teacher, a full semester.

I thanked the teacher. There were lessons learned and taught that day, and there was also envy — for the opportunities that await our eight, nine and ten-year-old children. They will be alive when man strolls to the rim of the great rift valley on Mars and soars past Jupiter and Saturn. They will hear recordings of the first SETI contact, and understand when the computers decode its hidden message. Some of them will probably work in orbit as I work at a typewriter, and they will have an intuitive understanding of those cosmic issues that are even now being hotly debated at Cornell, Stanford, Harvard, and MIT.

The critics of American public education have some valid points when they point out that Soviet children are better educated in the mechanics of mathematics and science. But these children are being trained — rather than educated — under a system that sees them as instruments of state policy. Our third graders have the precious right to wonder and to ask, and if you have the chance to meet them as I have, you'll be encouraged.

"Do you know what causes an eclipse of the Moon?" I asked my son the other night.

"It's when the Earth sort of sticks its fanny in the Sun's face," he suggested with a giggle.

I couldn't have said it better myself.

Mike Brake
Oklahoma City, OK

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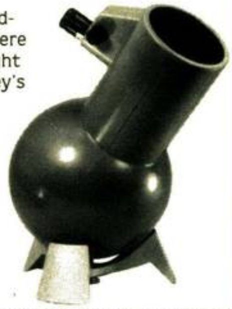

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ASTRONOMY
In Focus

Happy Birthday, Edmond Halley

Sir / As an astrophysicist and author of *Halley's Comet: A Viewers Guide*, I'd like to suggest the 329th birthday of Sir Edmond Halley on November 8 as an opportune time to acquaint the public with the joys of astronomy. The comet should then be observable with small telescopes, and a month or two later should be visible to the naked eye. As this will be his last "birthday" before the comet leaves, it would be a perfect time for Halley birthday parties all over the world. For suggestions on organizing the event, contact me at 138-78, California Institute of Technology, Pasadena, CA 91125; phone (818) 795-0147.

Dr. Thomas R. McDonough
Lecturer in Engineering, Caltech
SETI Coordinator, The Planetary Center
Pasadena, CA

What *Is* that Mysterious "#"?

Sir / Your inclusion of BASIC programs is a welcome addition to your excellent magazine. While I have had no trouble with SUNNY.BAS, the next program, PRECESS.BAS, crashed. I had just started typing in your latest program, HALLEY.BAS, when I noticed that lines 860 and 1100 include a "#" — the same symbol that caused the earlier problem.

I am unfamiliar with any dialect of BASIC that uses this symbol, so I don't know how to convert it to my dialect. Could you please tell me what it stands for, or where I can find this information? I am looking forward to using these programs, but right now they have me stumped.

Herb Wexler
Canoga Park, CA

— Our BASIC attaches the # suffix to any number it interprets as a double precision constant. This is standard in all versions of Microsoft BASIC-80, Release 5 that we've seen. You can simply omit this character when you input the program, declare the variable as double precision, or make a DEFDBL type declaration in other BASICs.

Halley Sites

Sir/ Our group of amateur astronomers have saved and saved and are going to the tip of Baja for one week to observe Halley's Comet.

We have a problem choosing the right time to plan this trip. We've read such conflicting reports regarding which month to pick that we would like you to answer the following questions, please!

1. Between November 1985 and April 1986, when is the best time for viewing and why?
2. During the best month, would it be morning or evening viewing?
3. Since there is considerable speculation regarding the viewing possibilities, is there a chance we will be able to see much from that geographic location?

Patti Marsh-Lumen
Visalia, CA

— April 1986 is the best month to view Halley: the Moon is out of the way from about the 3rd to the 14th; Halley is at its brightest, shows its longest tail, and transits from 4:30 a.m. on the 5th to 12:10 a.m. on the 14th. During this period, Halley transits about 30 minutes earlier each day. The tip of Baja is a great choice, but you'd do even better going farther south.

Sir / I am a regular reader of your magazine and hope you will not mind my writing to enquire where in Europe one could observe Halley's Comet during 1986.

I see from your recently-published advertisements that there are cruises to the Amazon, trips to Mexico, and also tours to South Africa offered for viewing the comet, but would one be able to observe it from somewhere in Europe?

T.B. Clark
Kent, England

— Yes, Comet Halley will be visible from Europe. As it descends toward the Sun in December 1985 and January 1986, Halley will be visible in the west during evening twilight. The best part of the apparition is, however, below your horizon. From March '86 to the end of April, when Halley passes closest to Earth and is at its brightest, the comet just skims the southern horizon from 40°North; it will be below the horizon from your latitude (around 52°North). By April 21, Halley will be visible very low in the southeast during evening twilight. Its brightness fading steadily, Halley climbs higher each night, slipping past Corvus the Crow and moving up toward Leo the Lion. By May 15, it will be visible only with binoculars or a small telescope.

Starlight Nights

Sir / As an "intensely" interested observer of image intensifiers (having bought a surplus military unit myself), I found "An Intensified Evening at the Telescope" (February 1985) most enjoyable. I would like to offer the following thoughts and advice:

- Purchase a *new* amplifier unit, one designed for astronomical photovisual work. The military units are designed for other purposes and are not up to par for astronomy, though I understand they can be upgraded by intensifier companies to a fair "sky level."
- The intensifier manufacturers will have to lower their prices if intensifiers are ever to catch on with amateur astronomers. It could be done through "surplus outlets" to company employees or build-at-home kits, etc.

Only when prices are substantially lower will a significant number of astronomy types purchase intensifiers.

- I discovered an unmentioned effect: "the starlight" can easily "see" through the visually opaque glass filters used in infrared photography. This should have some use in astrophotography, I think.

Ron Smith
Sharon, MA

— Thanks for the tips. Intensifiers ought to be incredible in combination with the new Ultra High Contrast nebular filters, and should also offer fantastic opportunities with H-alpha passband interference filters. We don't know why no one has yet used them this way. (Hint, hint.)

Halley from Tahiti?

Sir / Of course, the southern latitudes of high 30° and low 40° — Australia, New Zealand, and South America — sound inviting, but their extreme distances mean extreme costs. Knowing this, some readers might be planning to combine lower cost and romantic South Seas enjoyment by visiting the fabled island of Tahiti (17.5° south latitude, 149.5° west longitude).

The purpose of this letter is to warn prospective visitors that a great obstruction to the south celestial pole exists in the form of 7,337-foot-high Mt. Orohena, which covers much of Tahiti. The only town, Papeete, lies on the northwest shore, with a few resort hotels in the suburbs. Therefore, you're going to want comet-viewing points *south* of the big mountain.

I can end on an optimistic note if the editor will provide the name of a possible south-shore hotel your travel agent could book.

Robert F. Geise
San Diego, CA

— We checked with a local travel agent, who said that the little "town" of Taravao on the southwestern side of the island has a hotel — the Hotel Tahiti — which, we were warned, is not to be confused with an identically-named hotel in Papeete.

The agent also cautioned that road travel from Papeete to the south shore takes a lot longer than it might appear on a map — anyone intending to nip out of Papeete and race over to the south shore to catch the comet before sunrise may want to rethink their plans.

Ooops!

In "14 Special Stars" (ASTRONOMY, April 1985), Jupiter's mass should have been given as $\frac{1}{100}$ that of the Sun.

Don't Rule Out Binoculars

Sir / Ten years ago I pleaded with my parents to invest in a good quality telescope, as I was filled with a need to satisfy my curiosity about the parade of lights above. I was then a senior in high school. They eventually broke down and purchased a nice 3-inch refractor for me as an early graduation present. For a little over a year, I kept concise notebooks on planetary movements, Jupiter's satellites, sketches of the Moon, etc. But after I entered college and eventually went into teaching, I somehow lost my "astronomy fever."

Last summer while unpacking some boxes that had been in storage, I ran across those notebooks. Reading them over, I felt the old curiosity returning — who wouldn't! — so I bought a good beginner's 2.4-inch refractor. The mystery and wonder came right back, full force.

Now — to get to the point of this letter. Recently I traded several handwritten letters from past astronomers for a pair of 11x80 binoculars. With their 80mm aperture — three inches more than my 2.4-inch telescope's — I am now a firm believer in the importance of aperture.

The views I get of Orion and its nebula are as breathtaking as those of the nearby Pleiades. Eventually, I'll need a sturdy mount to hold the 11x80s steady, but the investment will be worth it.

To sum up, don't rule out binoculars when it comes to sky watching. And with Halley soon to be a reality for backyard astronomers — watch out!

Lynn Pruett
Beeville, TX

Behind the Scenes

Comet Fever

You may have already noticed the rising level of interest in astronomy. Your family and friends, the people you work with, or even your dentist may have asked you when they could see "The Comet." If you belong to an astronomy club, there's been serious talk of driving to Mexico or flying to New Zealand. Well, you can imagine what things are like at ASTRONOMY — we're seeing an unprecedented level of public interest in sky watching.

Interest in our February Gazer's Gazette article, "Computing the Ephemeris of Comet Halley," was little short of amazing. Custom versions of our "generic" BASIC program soon appeared on CompuServe for Commodore and Heath computers, and we received numerous letters from readers. Our "Return of Halley's Comet" poster has become this year's "runaway best seller" for us — and it hasn't even reached the planetariums and bookstores yet. The way things are going, don't be surprised if a copy of this poster plops out of your next box of breakfast cereal.

AstroMedia's book *Halley's Comet!*, due for release in mid-summer, already looks like another sales champ. For ASTRONOMY's regular readers, the book's big attraction is its detailed finding charts. To the general public, *Halley's Comet!* offers short but informative chapters on comets designed to answer most beginners' questions.

Meanwhile, we're not neglecting the comet in ASTRONOMY. As it draws closer and gets brighter, we'll bring you more detailed articles on observing, drawing, and photographing Halley. We begin, in this issue, with a short rumination on the comet's anticipated visibility. If you read carefully, you'll realize that there are only two brief periods for northern hemisphere observers when the comet will be naked-eye bright — one in early January and another in early to mid-April.

Of course, observers with binoculars to small telescopes will be able to follow Halley longer — probably from October to May, with a gap in the middle around the time of perihelion. But enough said now. We'll continue our coverage next month. . . .

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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Observing Prospects for Halley

Gazer's Gazette

On June 12, Comet Halley reaches solar conjunction; on that date, it will be a little over 5° south of the Sun. Through the rest of June and all July, it remains lost in the solar glare — and even if it were better placed for observing, it's still too faint for amateur instruments.

So why even think about Halley until it emerges from the solar glare and starts getting brighter? The answer, in a word, is "preparedness." If you want to observe Halley's Comet from the northern hemisphere, then you'd better start getting ready *now* because it's going to be a significant observing challenge.

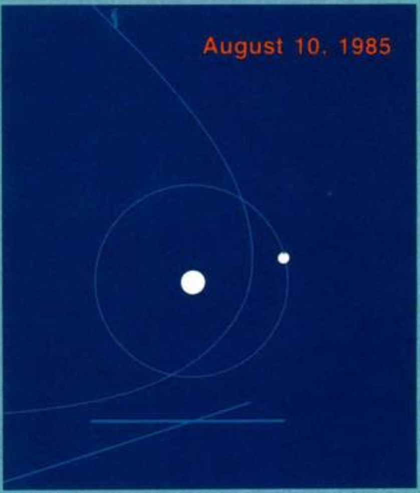
Here's why: Comet Halley's orbit is inclined to the plane of the ecliptic (the plane of Earth's orbit) by about 18°. When Halley is far from the Sun, its orbit lies below (i.e., south of) this plane, but the comet is now fairly high in the northern sky because that part of the ecliptic is well north of the celestial equator. As Halley approaches the Sun, it very slowly approaches the ecliptic plane moving northward. At perihelion, when the comet is nearest the Sun, its orbit carries Halley above (i.e., north of) the ecliptic. On the face of it, this looks good for northern observers.

But *where* we see Halley *in Earth's sky* critically depends on where Earth happens to be in its orbit at the time Halley swings past the Sun. At the 1985/86 apparition, the comet crosses the ecliptic plane northward in early November '85; it does not re-cross it moving southward until early March '86. Where Halley is below the ecliptic, the ecliptic is well north of the equator, so while Halley is far from the Sun, it is well-placed for northern observers. So far, so good.

When Halley crosses the ecliptic in early November, moving northbound, it does so near the northernmost part of the ecliptic in Taurus. Only 1.5 AUs from the Sun, it makes its first close approach — 0.62 AU — to Earth in late November. But while the comet speeds *toward* the Sun, Earth continues in its orbit *around* the Sun so the two separate rapidly. Halley remains above the ecliptic plane, but for Earth-bound observers, the ecliptic plunges south.

When Halley reaches perihelion on February 9, 1986, Earth is almost on the other side of the Sun from the comet. Halley then lies a mere 8° from the solar disk and 1.5 AUs distant from Earth.

Now comes the real joker. After perihelion, as the comet reaches greatest brilliance and rapidly recedes from the vicinity of the Sun, it approaches Earth a second time. As the comet-Earth distance decreases through February and March, Halley drops below the ecliptic plane on March 10. But since the ecliptic is far south of the equator here, when Halley approaches Earth, the double southward motions — Halley relative to the ecliptic, and the ecliptic relative to the celestial equator — compound their effects and Halley sinks toward lower and lower declinations. The April 10 date of the comet's southernmost excursion (−47°) and its closest approach to Earth (at 0.42 AU) almost exactly coincide.



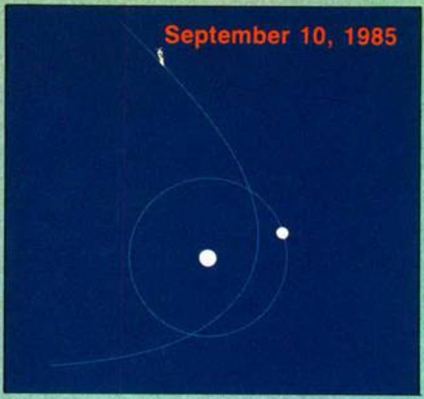
Halley's elliptical orbit and Earth's nearly circular path about the Sun are shown here at the same scale. The upper chart is a "plan" view of the orbits; the lower chart is a "side-on" view showing the 18° inclination of Halley's orbit.

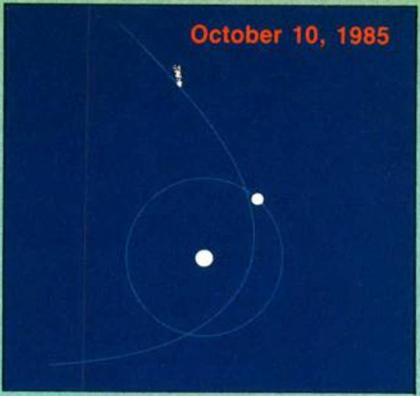
This is the bad news for northern observers: not only is the comet impossibly low in the sky, but it will have been moving away from the Sun for two months and will pass Earth at twice the distance of its 1910 apparition. The good news is that within a month Halley will have moved 30° farther north, making it again observable even though the comet-Earth distance will have more than doubled.

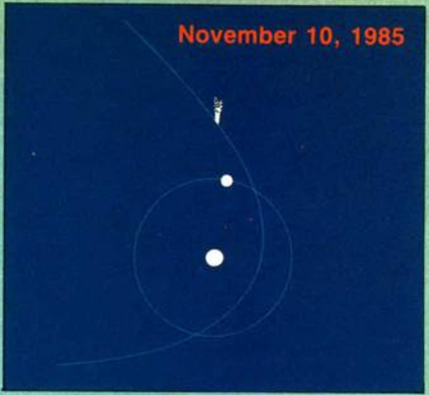
Observing Prospects for Halley

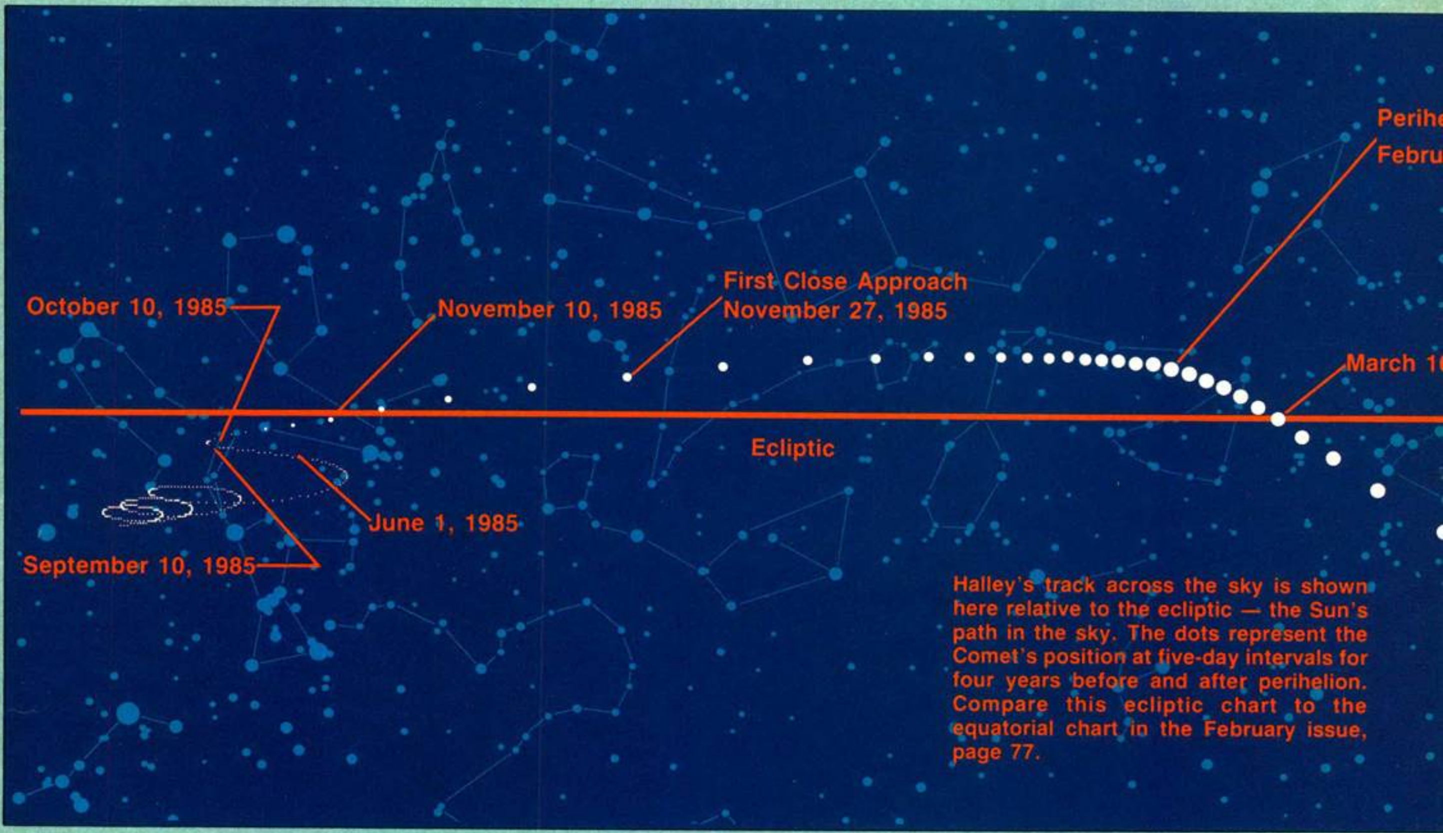
Buried in all this blather about Halley's orbit are essential clues to its visibility. There are basically five Halley observing periods in 1985 and 1986. The first period begins in August 1985 and runs until the early December, when Halley becomes visible to the naked eye. In August, Halley will be a morning object and best looked for when the Moon is absent between the 10th and 22nd. Rising earlier and earlier as it brightens, Halley will probably remain telescopic through September, October, and November. Moon-free observing times are September 10 to 25, October 5 to 25, and November 3 to 25.

The second period begins in December 1985, when Halley attains naked-eye brightness. If you're eagle-eyed *and* Halley gets bright faster than expected *and* you observe from a dark site, you might spot it sooner. In early December, Halley crosses the meridian shortly after the end of twilight and sets in the wee hours. With a total brightness exceeding M-13's, the comet should be easy to photograph with piggybacked cameras. Moonrise will interfere as early as December 7th, and by the 16th the Moon will be up whenever Halley is. With the comet's nuclear activity on the upswing, even moony nights will be useful for making detailed drawings of the comet's coma. At the beginning of January 1986, Halley will be traversing Aquarius, rapidly sinking in the west after sunset. On the 12th, the









Halley's track across the sky is shown here relative to the ecliptic — the Sun's path in the sky. The dots represent the Comet's position at five-day intervals for four years before and after perihelion. Compare this ecliptic chart to the equatorial chart in the February issue, page 77.

crescent Moon joins it, and on succeeding nights rapidly waxes and climbs into the sky. By the 20th, Halley sets before the end of twilight and is lost.

A few weeks after Halley swings past the Sun and then dips south, the third observing period begins. Although southern hemisphere observers may be able to pick up the comet in early March, northern observers won't see it until mid-month — if then. Skimming the southern horizon, Halley is now at its brightest; unfortunately, it will look pretty weak low in the sky with a bright interfering Moon. The Moon is absent after April 5, but Halley reaches its furthest point south on the 10th. If the comet is active, however, northern observers may be treated to its long tail rising out of the horizon murk. It won't hurt to look.

The fourth period begins on April 15 when Halley starts moving north again, though with a brightening Moon in the sky, it won't be very impressive visually. This is probably the best time to observe the active nucleus and coma at high magnifications. By May 1 the Moon will be gone again, but Halley will have dimmed toward the limits of naked-eye visibility. Northern hemisphere astrophotographers should be shooting some of their best pictures during the moonless interval before the waxing crescent joins the fading comet once more in the evening sky on May 11.

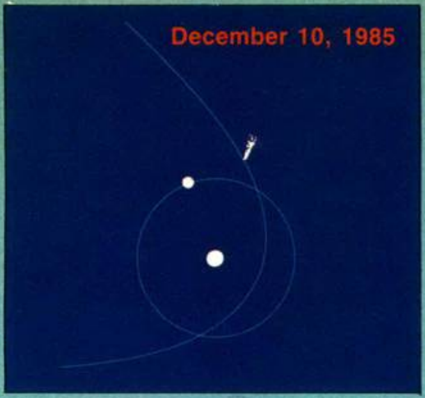
During the fifth and final observing period, Halley again becomes a telescopic object. It will be clear of the Moon during the first and last weeks of June. Since it is receding rapidly from the Sun, Halley now loses a magnitude every 10 days — three magnitudes by the end of the month. By August, Halley will set as night descends and so will be lost to observers until the fall.

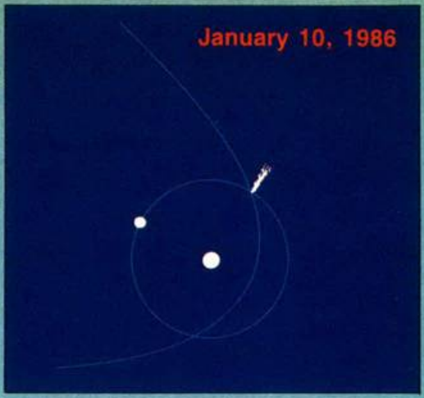
Halley "Preparedness"

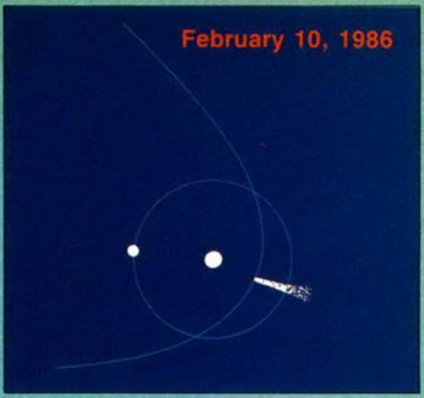
What should you do to get ready for Halley's return? Well, if you want to travel to South America, New Zealand, or Australia for a better view, you'd better make your reservations now. Space is bound to be limited. Oh yes — if you sign onto a tour, determine in advance whether it's primarily a "sightseeing tour" or an "expedition to view the comet."

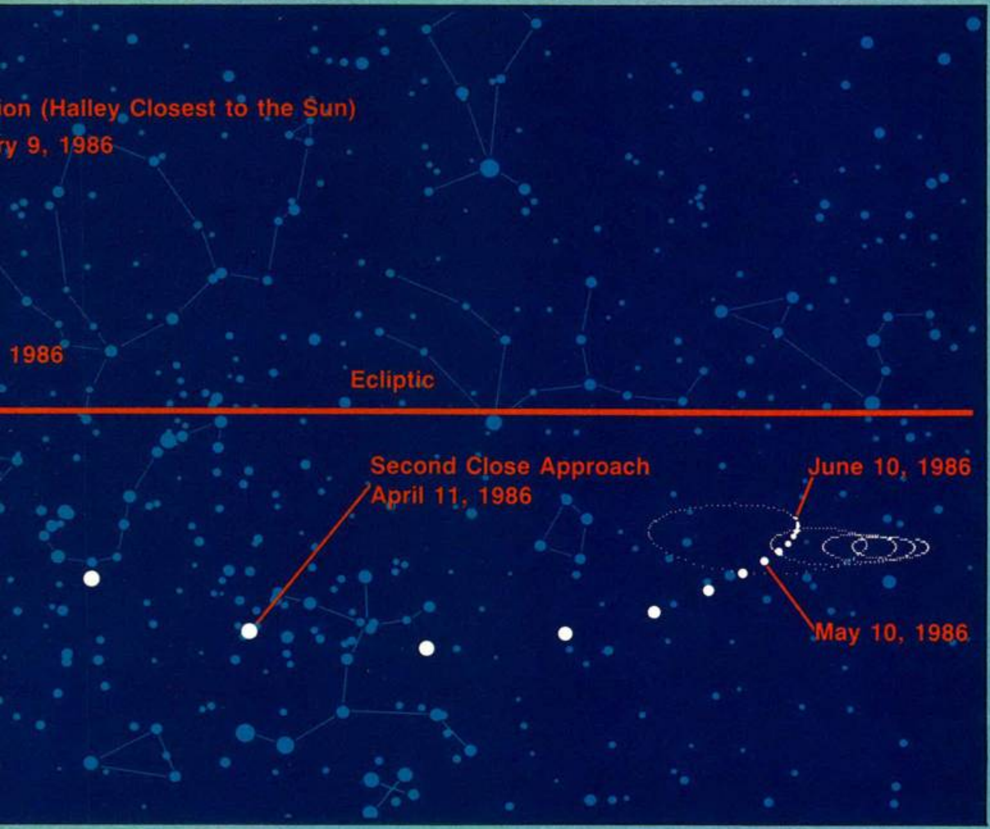
If you don't intend to leave your native hemisphere, start by finding yourself a dependable dark-sky observing site. You'll need unobstructed views of the eastern, southern, and western horizons, good access during winter (don't forget snow if you prospect for sites this summer!), and quite possibly electric power or other comforts of home.

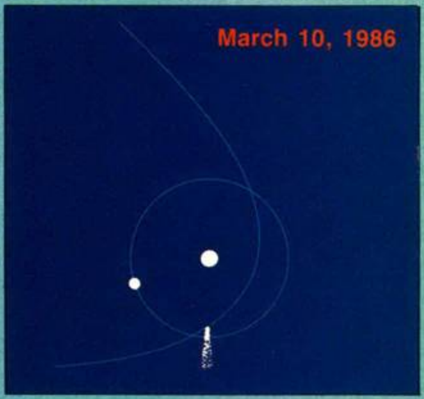
If you seriously want to participate in organized comet observation with the International Halley Watch, you'd better get cracking. It's now nearly too late to get enough experience to be effective. For information, see "Halley Watch '86," ASTRONOMY, March 1983, and to receive the I.H.W. Amateur Observer's

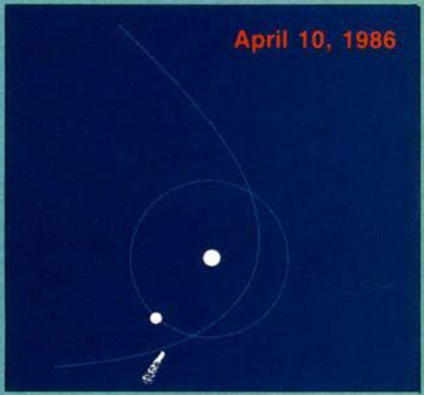


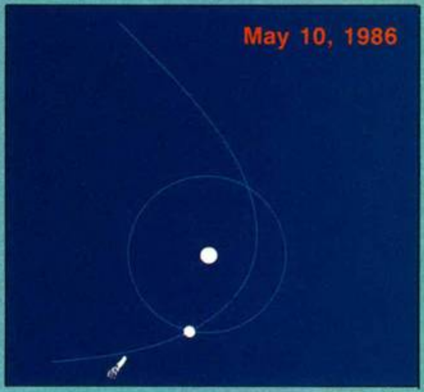












So near and yet so far: Comet Halley and Earth play hide and seek as they orbit the Sun during the 1985/1986 apparition of this famous comet. This sequence shows the positions of Halley and Earth at one-month intervals, approaching, then receding, approaching again, then receding — but never coming close.

Bulletin, send your name and address to P.O. Box 91687, Pasadena, CA 91109.

It would be a good idea to arrange special work hours in advance — especially for the January apparition. You will need an hour or two to drive from the city, set up your telescope, and get ready to observe. It would be a shame if you had to wait to go until 5 p.m. on the first perfect, clear night in two weeks — only to arrive at your observing site 30 minutes after Halley had set. Plan ahead!

In order to locate Halley quickly and efficiently, start brushing up on your constellations *right away*. Of course you already know Pegasus, Aries, and Taurus (don't you?) — but you'll also need to know the dim stars of Pisces, Capricornus, and Aquarius to be sure of finding Halley when it plunges into evening twilight in January. For its reappearance low in the April sky haze, you should be a whiz at finding Sagittarius, Scorpius, the northern stars of Centaurus, Corvus, Crater, and Hydra.

If you want to make photographs and haven't done astrophotography before, you'd better get started this summer. Try star trails during the dark of the Moon this month, 50mm lens piggyback photos next month, and telephoto piggyback shots the month after. Get each roll of film developed promptly, inspect the results, and learn from them. By the fourth month, you'll be ready to start photography through your main telescope — maybe.

Expect the Unexpected

In anticipating the events of the upcoming Halley flyby, it's easy to portray the event as (ho-hum) pretty cut-and-dried. It's not. No one really knows what Halley will do. It *will* follow its orbit and it *will* be fairly dim. Beyond that, it's guesswork. No one knows how active the comet will be. No one knows how bright it will be. No one knows . . . many things. We'll all find out together.

— *Richard Berry*

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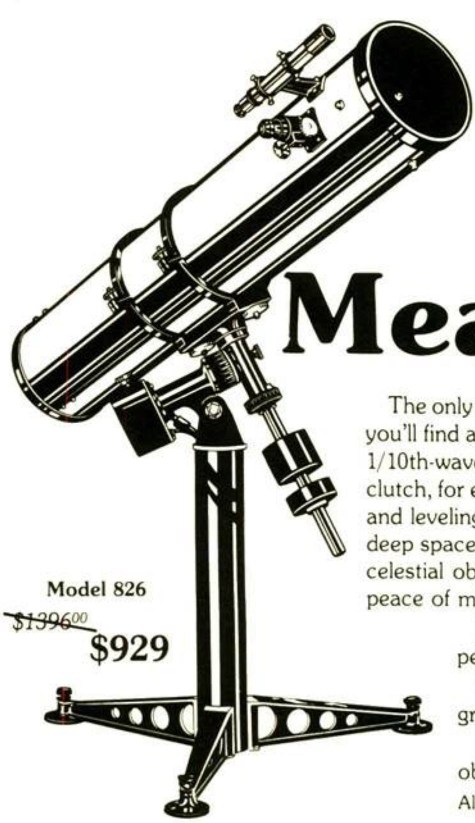

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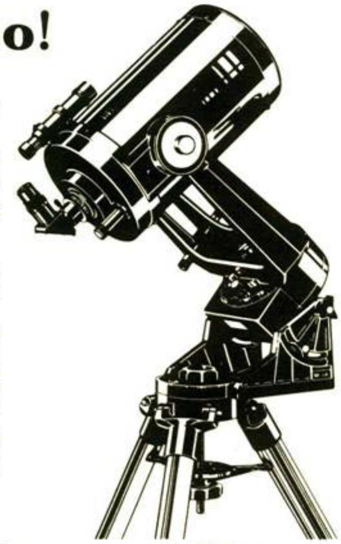

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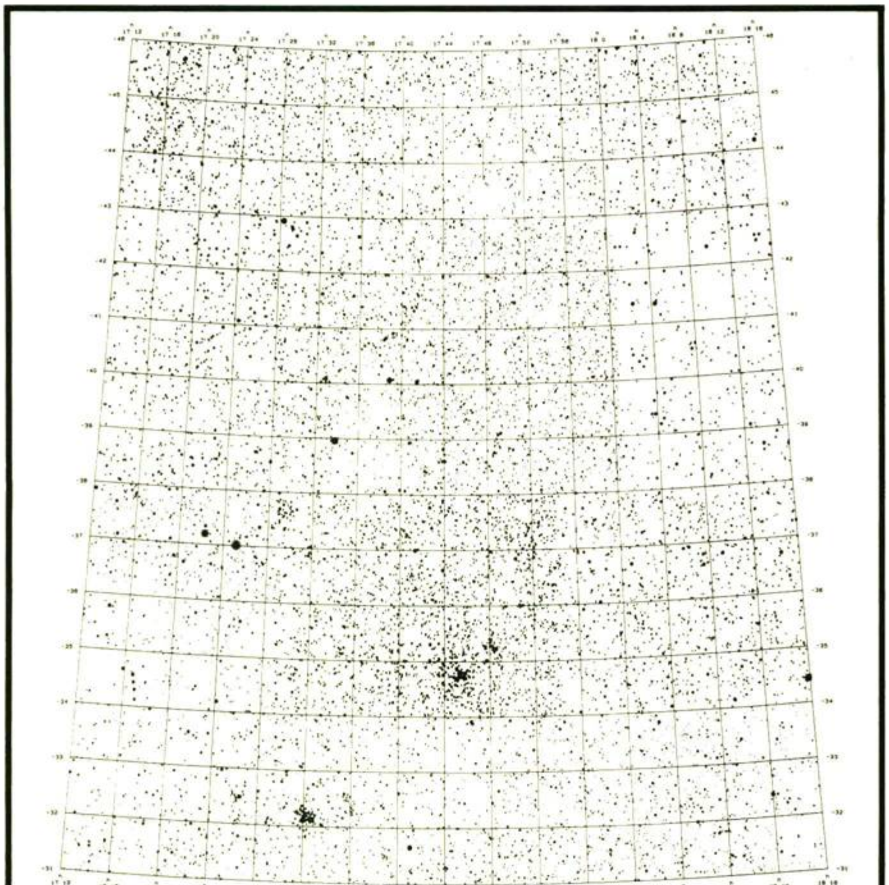
ASTRONOMY
Reviews

Cape Photographic Durchmusterung Star Atlas
Barry Rappaport
113 charts, laminated, $600; unlaminated, $450
Astrocharts Unlimited (1984)

Deep charts of the southern sky have been hard to come by — until now. Barry Rappaport has done southern hemisphere astronomers a service with his computer-plotted *Cape Photographic Durchmusterung Star Atlas*. Based on the famous star catalog compiled by Gill and Kapteyn between 1895 and 1900, the *CPD Star Atlas* plots some 450,000 stars down to magnitude 10.5 — and many areas down to 11.5 — from declination −19° to the south celestial pole. The CPD catalog lists stars by their photographic magnitude, a "blue" rather than "photovisual" scale.

Each chart is 22 inches square, with a trapezoidal star-filled "live area" roughly 18″ high by 16″ wide spanning 15° in declination. At 30 millimeters per degree (a scale four times greater than that of *Sky Atlas 2000.0*), the enormous number of stars present crowding problems in a few areas, but for the most part, the charts remain readable and open. Each has a graticule at 1° intervals in declination and roughly degree-wide spacing in R.A.; the epoch of the coordinate grid is 1875. Adjacent charts overlap 1°.



Any atlas showing stars fainter than 10th magnitude is bound to suffer some problems in depicting a 10,000:1 range in brightness with star symbols that span a mere 20:1 in size. The largest symbol, for stars 1.5 magnitude and brighter, is a circle 5 mm in diameter with a 3.5 mm filled center. The faintest stars, those of 11th magnitude, are 0.3 mm dots. The greatest number of dots on the charts are 1 mm in diameter, and represent stars dimmer than magnitude 8.5.

The *CPD Star Atlas* shows only stars: no other objects are plotted. In this respect, it's like the old *Bonner Durchmusterung*. To the amateur astronomer brought up on the rich wealth of clusters, nebulae, galaxies, and other deep-sky objects plotted in Antonin Becvar's *Atlas Coeli* or Wil Tirion's Sky *Atlas 2000.0*, these charts may seem a bit dull. But for the professional astronomer interested in identifying a specific star for photometry or spectroscopy, they should prove invaluable. *Richard Berry.*

JSO-12B 125mm Schmidt-Cassegrain Telescope
$795
Medea Trading Co., Inc.

Mizar AR-1 Equatorial Mounting
$650
Medea Trading Co., Inc.

Medea Trading Company's new import offering, the JSO-12B 125mm f/10 Schmidt-Cassegrain telescope, is a remarkable example of the excellent astronomical instruments now made in Japan. An evaluation unit, serial number 83071138, was provided us by Larry Jones of Medea on a three-month loan.

The Japanese philosophy of telescope

design differs from the American at every level, and the differences begin right with packaging of the instrument and its numerous accessories. The instrument arrived in three sturdy cartons: one containing the telescope, the second the equatorial mount head, and the third the legs of the tripod. The telescope carton contained a silver-colored, fitted carrying-case lined with red velveteen.

The mount parts were securely packed with Styrofoam inserts and bubble wrap. Although the owner's manual was still in preparation, the photocopied sheets supplied by Medea were clear and easy to follow. The total "unwrap, cogitate, and assemble" time, from cutting the packaging tape down to installing the last tiny battery was about two hours.

It's in the assembly that the Japanese philosophy next becomes apparent. The package is a complete kit, carefully thought-out. In separate small boxes packed inside the main mount box were the clock drive motor, the polar alignment telescope, the crosshair alignment light, and the extension slow-motion rods. Everything I needed — wrenches, Allen keys, batteries, little gears, screws, even a carrying bag for the drive motor — was provided, ready to go . . . or so it seemed.

The telescope attaches to the mount by means of a dovetail slide, which allows the telescope to mate and demate quickly from mounts or tripods. The slide, however, arrived without holes for mounting on the equatorial. Since it appeared to be made of aluminum, I decided to drill the holes myself. Ten minutes later, with two ¼" holes drilled and countersunk, the telescope sat atop the mount. Jones assures me that future instruments will be shipped with dovetails already drilled.

The equatorial is a compact German mounting, which features a polar alignment telescope with illuminated crosshairs. I simply screwed it into the polar axis without bothering to calibrate it. Later, however, I did check and found it had arrived accurately calibrated. Installing the pulse motor (which runs from four D cells) took a little head scratching, but the whole drive unit went together in about 15 minutes.

The proof of the pudding is in the observing. The assembled mount is light enough to carry outside, even with the legs fully extended. I set it in the backyard in the shadow of the garage away from the alley light and attached the telescope with the dovetail slide. This feature is very convenient.

The polar alignment telescope is impressive. It took a couple of minutes to place Polaris exactly on the ring. The mount adjustments were very smooth and were free of backlash. I noticed that I got some grease on my fingers from the bolts. I really can't complain, though, because equipment that's intended for use at night *should* be properly lubricated and protected from moisture.

With the telescope now aligned, I switched on the drive and plugged in a high-power eyepiece. The telescope tracked perfectly all evening, not only at the right rate, but without noticeable drift in declination! The alignment telescope really works. The drive comes with a hand-held switch that allows the observer to stop the motor or run it at double speed. The action was quick and sure, and quite adequate for guided piggyback photography — even with long lenses.

The mount, in addition to tracking well, is exceptionally steady. The settling time, following a sharp tap on the telescope, its mount, or the legs, is about a second, and the amplitude of the initial oscillation is small. On the negative side, the setting circles are so small that they are nearly useless, and the accessory tray between the tripod legs isn't large enough to hold much. These are hardly serious shortcomings, but they are annoying.

The JSO-12B is more than an exceptionally solid telescope — it's built like a rock! The tube is strong, it's nicely machined, and nothing rattles when you shake it. The lens cover, a skimpy pie tin on many telescopes, is a tight-fitting machined casting which — to me — exemplifies the quality construction throughout. Firmly mounted on the Mizar mount, the optics of the telescope were easy to evaluate critically. The focus is incredibly smooth, has NO backlash, and

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produces no unwanted lateral motion. Would that all SCT focus systems were so good.

I performed exhaustive star tests on three separate nights. Though the optics are not perfect, they compare favorably with the images I've seen in other Schmidt-Cassegrains. At 400x on Vega there was a faint halo of scattered light around the star image, and I noted a slight asymmetry in the Airy disk due to what looked like an octagonal pattern polished into the corrector lens. (I've seen a similar problem in domestic SCTs, too.) In Ronchi testing, the bands appeared perfectly straight except for slight roll-over at the outer and inner edges of the aperture — a relatively minor defect that causes the halo. Incidentally, these errors would probably pass unnoticed by the average user and degrade performance only slightly.

When fully cooled, the instrument gave good images of Saturn and showed Cassini's Division reasonably well. It revealed Jupiter's cloud belts nicely, including subtle white ovals visible in several of the dark bands. The First Quarter Moon showed a wealth of detail.

Despite generally well-corrected optics, the large secondary obstruction (40%) reduces image contrast in planetary viewing and produces a less-than-ideal diffraction pattern for critical splitting of double stars. Nevertheless, I was able to split Epsilon Bootis — a double with a large magnitude difference — with little difficulty. The "double double," Epsilon Lyrae, with its near-equal pairs of components, was even easier. Though the images do not compare with those of an unobstructed instrument, an equivalent f/15 refractor would be over six feet long.

In all, I found the JSO-12B telescope and Mizar AR-1 mount to be a functional and versatile instrument. During the two months I had it, I was impressed again and again with how convenient the unit is for nightly use. I would especially recommend it to apartment dwellers and others for whom space is at a premium. Both telescope and mount are carefully thought out and well constructed; they should provide years of good service. Overall, the JSO-12B is an above-average value in its aperture range. *Richard Berry.*

Physics of Planetary Interiors
G.H.A. Cole
208 pages, paperback, $16
Adam Hilger (1984)

This book gives undergraduate physics students a general introduction to the subject. It covers such topics as the size of planetary bodies, hydrostatic equilibrium, internal mass distribution, thermal effects, and magnetic fields. The final three chapters examine "large mass" planets (the gas giants), terrestrial-type planets, and planetary bodies composed mainly of ice.

Halley's Comet; a Bibliography
Ruth S. Freitag
555 pages, hardcover, $26
Library of Congress (1984)

Ruth Freitag is a science specialist at the Library of Congress; her bibliography on the comet contains 3,289 items. It includes books, pamphlets, periodical literature, broadsheets, newspaper accounts, catalogs, reminiscences, letters, music, drama, verse, orbit diagrams and models, photos, cartoons, and more. Most of these items are in European languages. Freitag "has not ruled out what even the most charitable judgment might dismiss as nonsense, since some of the more peculiar ideas about comets in general and Halley's Comet in particular are of historical or cultural interest."

Guide to Stars and Planets
Ian Ridpath
384 pages, hardcover, $19.95
Collins (1985)

The core of this book is 88 star maps by Wil Tirion that depict the constellations in alphabetical order. The maps fall on the right-hand pages, the left-hand ones contain commentaries describing the brightest stars and objects of each group. A set of month-by-month all-sky maps shows what constellations are visible at any time in the year. The book also includes hints and tips on telescopes and observing, and has maps of the Moon and Mars.

Spacelab: Research in Earth Orbit
David Shapland and Michael Rycroft
192 pages, hardcover, $29.95
Cambridge University Press (1984)

Spacelab, a mini-space station carried in the Shuttle's cargo bay, is a European Space Agency project that made its first flight on STS-9 in November 1983. As a taste of what the U.S. space station will be like, it was an outstandingly successful mission. This book is a popular level summary of the mission and its results.

Planetary, Lunar, and Solar Positions A.D. 1650-1805
Owen Gingerich and Barbara Welther
97 pages, hardcover, $20
American Philosophical Society (1983)
[Publisher's address: 104 S. Fifth St., Philadelphia, PA 19106]

This volume tabulates the positions of the Sun, Moon, and planets (through Saturn). The intervals are 5 days for Mercury, Venus, and the Moon, and 10 days for the Sun, Mars, Jupiter, and Saturn; the coordinates are tropical celestial longitudes and latitudes. In addition, there are tables of New and Full Moons for the same period.

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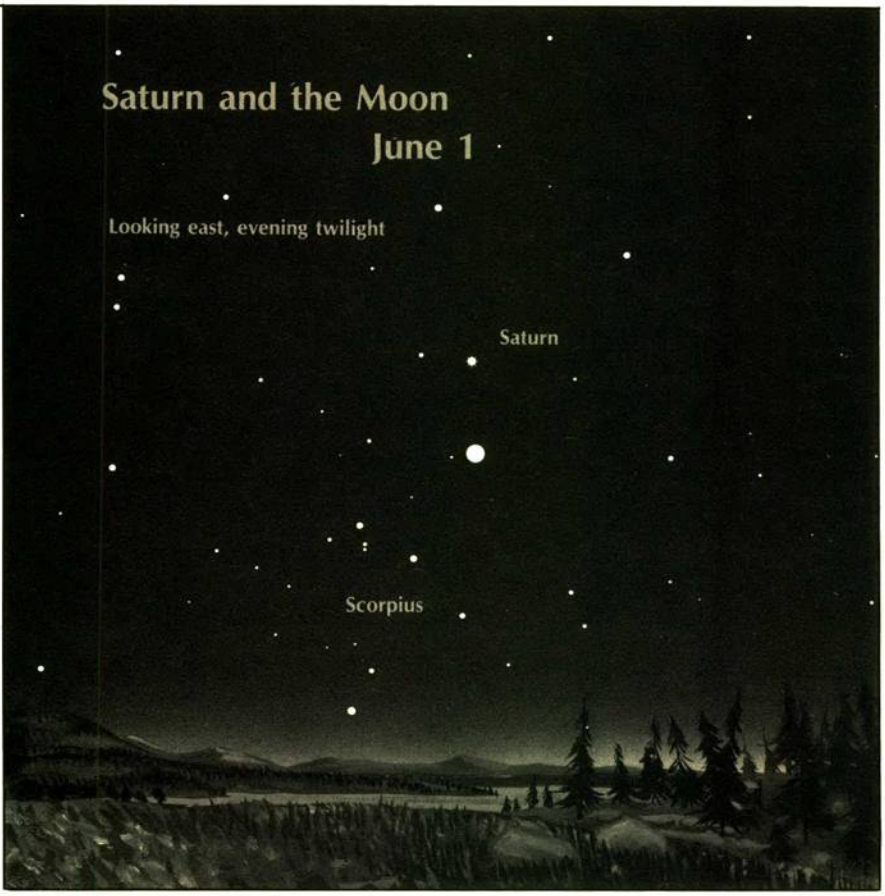
Summer Planetary Show

by Fred Schaaf



On May 10, 1984, Spica, Saturn, and Mars rose over Devil's Garden Campground in Arches National Park, Utah. Photo by Dennis Plichta; 28mm f/4 lens, 15-minute exposure, ISO 200 film.

The Wanderers

June is a month of few major celestial events, but the planets put on quite a show: most of them are at or near their brightest.

Mercury travels through Taurus into Gemini, passing Aldebaran early in the month and Pollux later in June. The first of these conjunctions will not be visible because Mercury is at superior conjunction with the Sun on the 7th (the planet also reaches perihelion — its closest approach to the Sun — on that day). By the 26th, however, when Mercury is about 5° south of Pollux, it is 20° from the Sun and coming into view in what will be a fairly good evening appearance. Look for Mercury 30 minutes after sunset by scanning in the west-northwest about 5° to 10° above the horizon.

Although dwindling somewhat in brightness and size, **Venus** is still an impressive object at magnitude −4; the planet is 45.8° from the Sun when it reaches greatest elongation on June 12th. Venus is a morning object in the early weeks of summer, passing into Taurus as the Bull begins to back slowly out of the dawn glow.

The brightest planet you will be able to see well up on early June evenings is **Saturn**, still at nearly zero magnitude. This month, Saturn wanders slowly westward, away from the dim naked-eye stars it encountered around opposition last month.

If you live around 40° north latitude, late twilight at the end of June will bring forth from the southeast the −2.5 magnitude giant **Jupiter**. Stationary on June 5th, the king of planets begins to backtrack in Capricornus, moving ever more rapidly toward opposition in early August.

Mars is hard to find this month. In conjunction with the Sun on July 18th, it is too low in the evening twilight to be seen without optical aid.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Our final planets to enjoy this month are the still mysterious worlds of Uranus and Neptune. In the case of Uranus, though, this may be the last summer we'll have to behold it with so little understanding — if all goes well, Voyager 2 will write another chapter in astronomical history when it passes Uranus next January.

Uranus is at magnitude 5.5 in June, so you should be able to see it with the naked eye on clear nights away from the worst of city lights. Since its opposition takes place on June 6th — just three days after Full Moon — you'll have to wait until later in the month to make this naked-eye sighting. This world can be found by locating the fairly bright star Eta Ophiuchi, but to find an object of Uranus' faintness, it is necessary to use a star atlas and precise coordinates. Check this month's Backyard Astronomer for help.

The same advice applies for would-be observers of **Neptune** — except to add that even in country skies, you'll need binoculars to detect this seventh-magnitude planet. But since it will be at opposition on the 23rd, why not try adding this huge planet to your itinerary of important places to visit this summer.

Three more events in June are of considerable interest. First, this is a month of two lunar perigees (the Moon's nearest approach to Earth) on the 1st and 29th. It is also the time of Summer Solstice. And this is the month when **Halley's Comet** is at conjunction with the Sun for the last time before we can see it with small telescopes, binoculars, and even the naked eye at year's end.

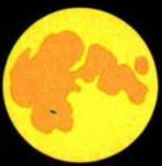
The Starry Sky

As June's constellations reach their highest in the sky, sunset occurs at its latest. And if your vacation takes you to dark skies, you may get some surprisingly rewarding views of the dim constellations which lie on the meridian as night finally falls.

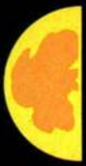
In the north, the end star of the **Big Dipper**'s handle — called **Alkaid** (Eta [η] Ursae Majoris) — is now high, as is brilliant **Arcturus** (Alpha [α] Bootis), the −0.1 magnitude luminary of **Bootes** the Herdsman. Along with **Spica** in **Virgo**, this handle and star usher into the west a grouping of rather faint constellations. One exception is Corona Borealis, the Northern Crown.

Corona Borealis is a celestial ornament consisting of a semicircle of six stars. Most of these stars are of similar brightness, but

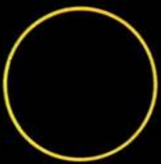
June's Night Sky



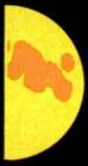
Full Moon
June 2
11:50 p.m. EDT



Last Quarter
June 10
4:19 a.m. EDT

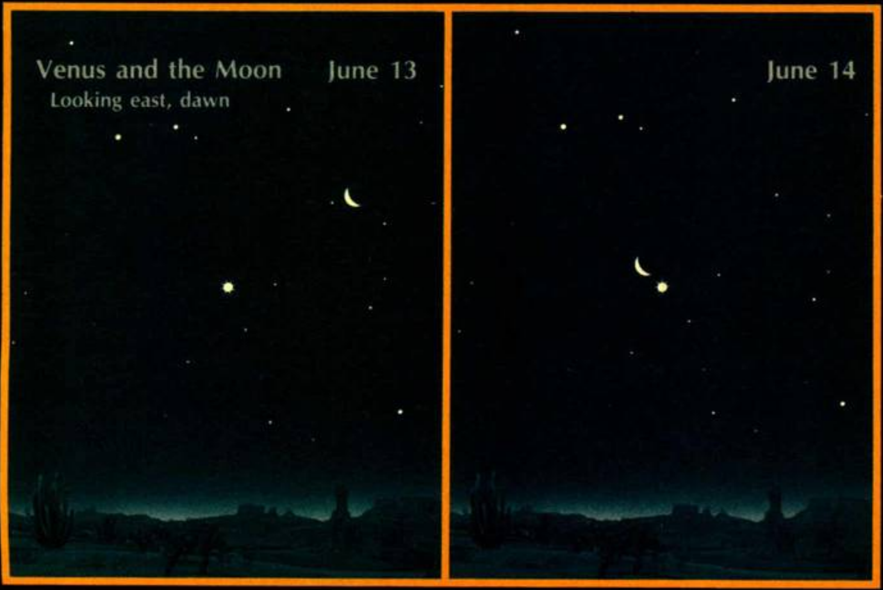


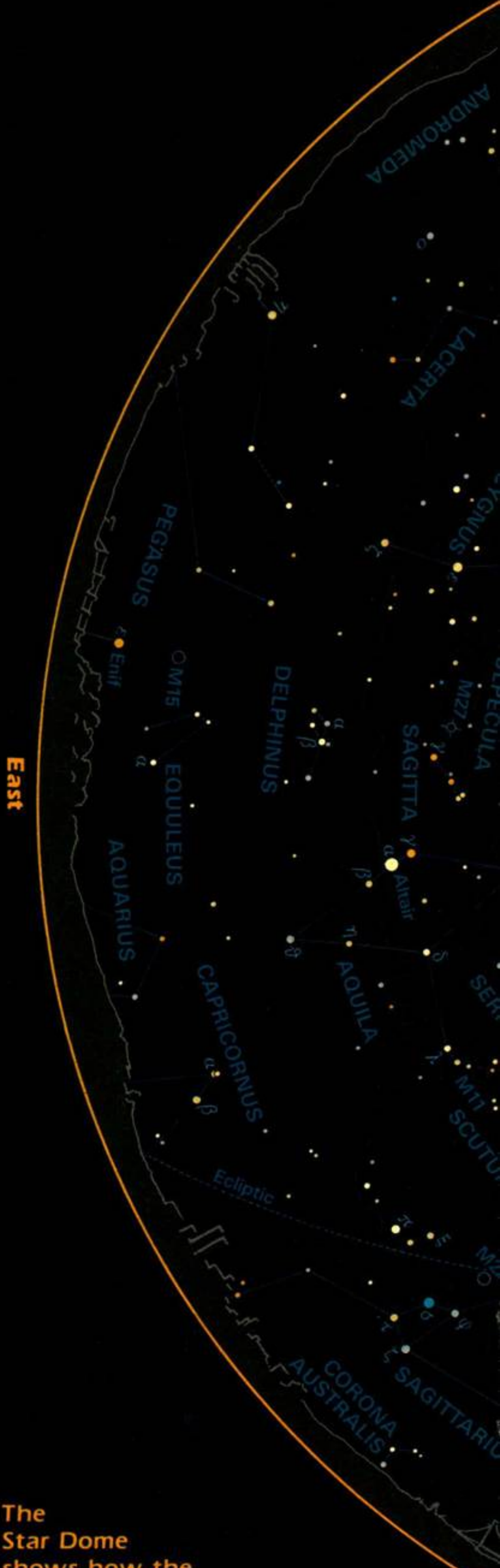
New Moon
June 18
7:58 a.m. EDT



First Quarter
June 25
2:53 p.m. EDT

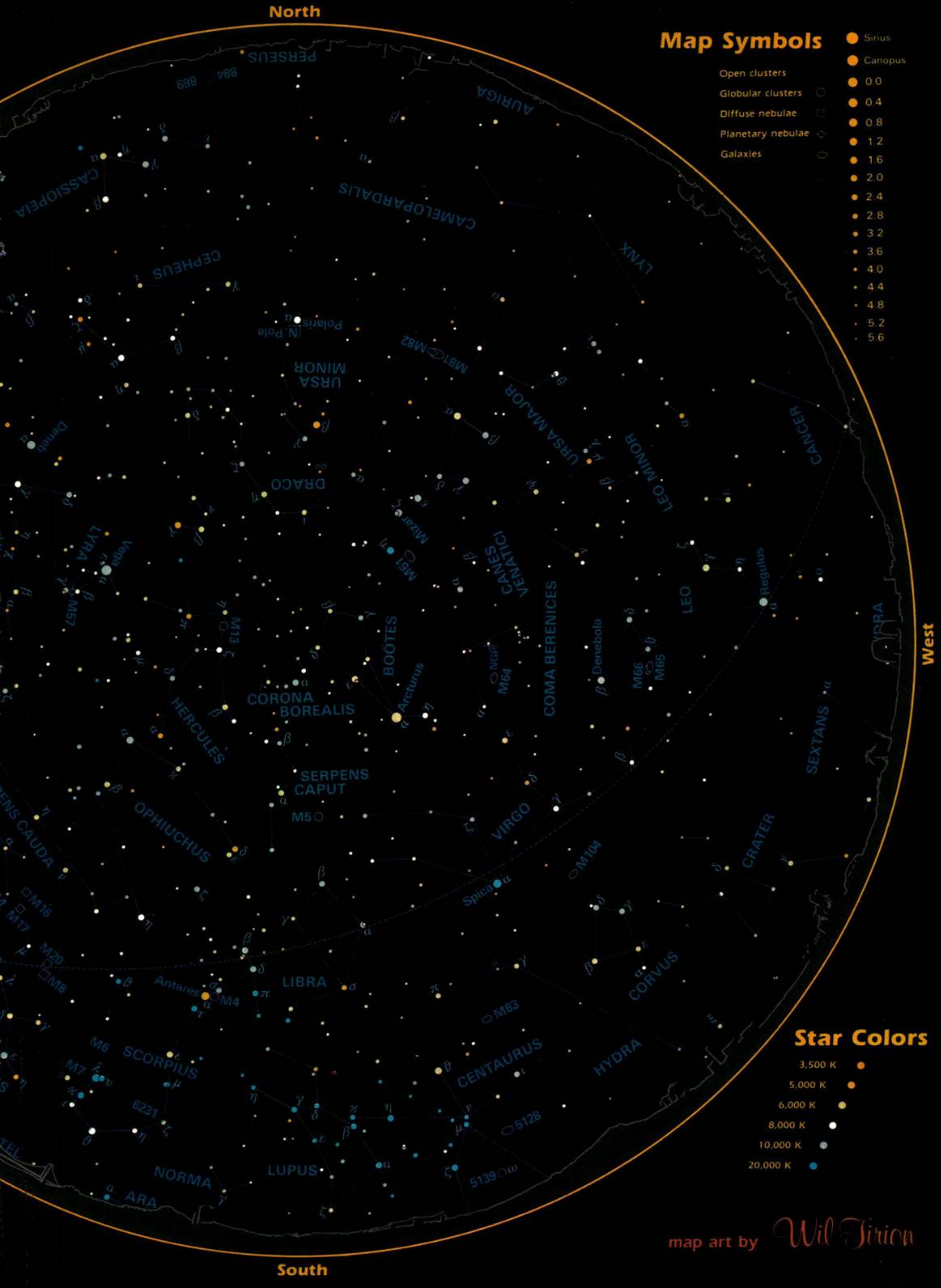
1st	The Moon is closest to Earth at 8:34 a.m. EDT: 224,264 miles. Look for the Moon passing 3° south of Saturn in the early evening (see diagram, page 42).
2nd	The Moon is Full at 11:50 p.m. EDT.
7th	At 10 a.m. EDT, Mercury is at superior conjunction with the Sun and on the same day at its closest to the Sun: 28.5 million miles.
10th	Last Quarter Moon occurs at 4:19 a.m. EDT.
12th	Venus is at greatest western elongation, 46° from the Sun at magnitude −4.
13th	The Moon is farthest from Earth at 10:05 a.m. EDT: 251,733 miles, and will pass north of Venus tomorrow. Start looking for them today in the early morning sky (see diagram below). Hint: This pairing would make a nice set of photos.
15th	Lyrid Meteor Shower reaches peak activity today.
18th	New Moon is at 7:58 a.m. EDT.
21st	The Summer Solstice ushers in summer at 6:44 a.m. EDT.
25th	The First Quarter Moon occurs at 2:53 p.m. EDT.
26th	Mercury will make a fairly good evening appearance 5° south of Pollux. Look for it 30 minutes after sunset in the west-northwest sky about 5 to 10° above the horizon.
29th	The Draconid meteors are at their peak. Once again this month, the Moon is at its closest to Earth at 5:19 a.m. EDT: 227,278 miles.


Venus and the Moon
Looking east, dawn
June 13
June 14


ANDROMEDA
LACERTA
PEGASUS
Enif
M15
DELPHINUS
SAGITTA
M27
EQUULEUS
AQUARIUS
Altair
AQUILA
CAPRICORNUS
M11
Ecliptic
CORONA AUSTRALIS
East

The Star Dome shows how the sky looks at:

Midnight on June 1st
11:00 p.m. on June 15th
10:00 p.m. on June 30th


North
South
West
Map Symbols
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
PERSEUS
884
869
AURIGA
CASSIOPEIA
CAMELOPARDALIS
LYNX
CEPHEUS
Polaris
N. Pole
URSA MINOR
M81
M82
URSA MAJOR
LEO MINOR
CANCER
Deneb
DRACO
Mizar
M51
CANES VENATICI
LYRA
Vega
M57
M13
BOÖTES
COMA BERENICES
NGP
M64
Denebola
M66
M65
LEO
Regulus
HYDRA
CORONA BOREALIS
Arcturus
HERCULES
SERPENS CAPUT
M5
SEXTANS
VIRGO
OPHIUCHUS
SERPENS CAUDA
M104
CRATER
Spica
M16
M17
M20
M8
Antares
M4
LIBRA
CORVUS
M83
M6
M7
SCORPIUS
CENTAURUS
HYDRA
6231
5128
NORMA
LUPUS
5139
ARA

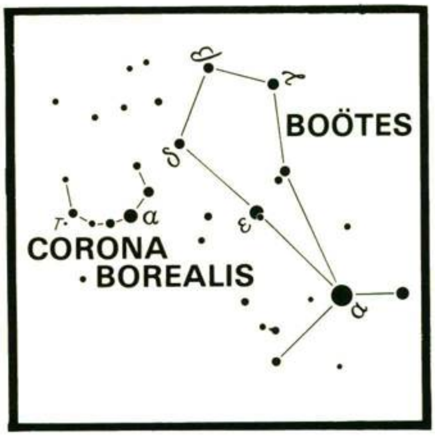
map art by Wil Tirion

Top: Orion was rising over some saguaro cacti when Frank Zullo captured this shot by taking six 15-second exposures, covering the lens and stopping down half a stop between each exposure (Ektachrome 200 film at f/1.8 with a 50mm lens). Bottom: This beautiful pairing of the crescent Moon and Venus shone over the Buffalo Bill Reservoir at sunset on January 15, 1983. Photo by Dewey Vanderhoff; 200mm lens, Ektachrome 64 film.

one — the Alpha star — stands out like a gem in the crown. It is **Gemma**, a second-magnitude star whose name actually does mean "gem."

Once you've found Corona Borealis, you need only go south a bit to locate a very compact triangle of dim stars and, farther south, a close pair made up of a moderately bright star and a dim star: **Alpha** and **Lambda** (λ) **Serpentis**. Alpha is sometimes called Cor Serpentis, "the Heart of the Serpent." These two arrangements join with other faint stars to form **Serpens Caput** — the Serpent's Head.

Where is the other half of the snake? South and east of Serpens Caput is another close set of faint stars: **Delta** (δ) **Serpentis** and **Epsilon** (ε) **Ophiuchi**. At this point, this constellation pattern is linked to **Ophiuchus**, the Serpent-bearer, pictured as a giant holding a snake. And if you look to the east of Ophiuchus, you'll see the Serpent's Tail, **Serpens Cauda** — the other half of the larger constellation **Serpens** the Serpent. The mid-section of the serpent clutched in Ophiuchus' hand is composed of stars which officially belong to him, even though they appear to be part of Serpens.



Serpens is the only constellation which has two parts completely separated from each other. Note that the stars of the Cauda and Caput parts all have their Greek lettering in order, and include stars from both parts as one constellation.

One of the stars in the line between Serpens Caput and Cauda is the rather bright Eta Ophiuchi, known as **Sabik**. During the 1980s, it has served as a guide star to two faint planets: for several years it helped locate Neptune, and now it aids in finding Uranus.

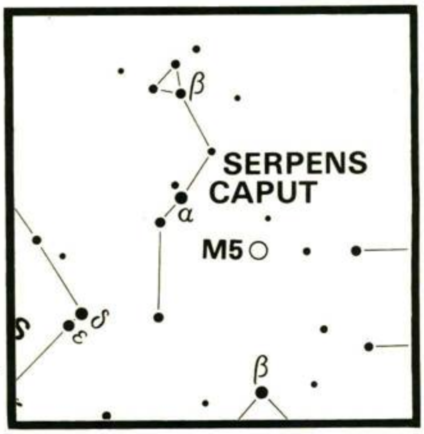
The vast outline of Ophiuchus encloses an area quite devoid of prominent stars — though it does contain a few globular clusters on the verge of naked-eye visibility and clearly detectable in binoculars. The head of the Serpent-bearer, however, is a very bright second-magnitude star called **Rasalhague**. And some degrees west of Rasalhague is another "Ras-" or "head" star, **Rasalgethi**. Although not as bright as Rasalhague, it is a beautiful double star system in small telescopes. Rasalgethi marks the head of another giant figure who is upside down in the sky: **Hercules**. Rasalgethi is Alpha Herculis — though actually Beta (β) and Zeta (ζ) are always brighter than this third-magnitude object.

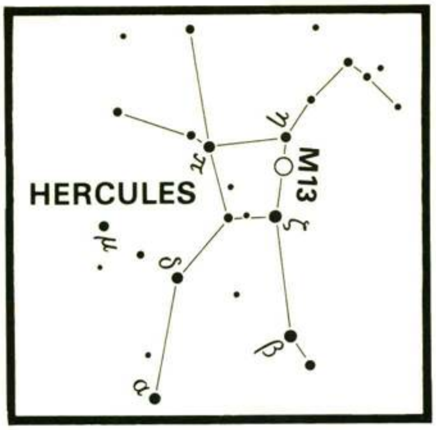
Zeta Herculis is the southwest star in a rhomboid which is the constellation's most interesting feature, known as the Keystone. Between Zeta and Eta Herculis glimmers a special treasure for observers. With the naked eye under dark skies, you can glimpse it as a magnitude 5.7 star, but binoculars or a small telescope reveals it as the mighty **M-13** — the great globular cluster of Hercules. Another Hercules globular is also beautiful, though slightly dimmer and smaller, and can just be glimpsed on the best of nights without optical aid. See if you can detect **M-92** with your naked eye at a dark country site under good conditions.

Skylore

Comets are being discussed everywhere these days, and rightfully so. Comet lore is nearly as spectacular, surprising, and varied as comets themselves.

Aristotle was probably about 13 years old when the comet of 371 B.C. appeared. According to this great philosopher, the comet was first observed near the Sun in the west and later developed a tail which extended across one-third of the sky — presumably about 60°. The Roman writer Seneca reported that the historian Ephorus of Cyme said this same comet divided into two parts. The skeptic Seneca regarded this as a fanciful falsehood that Ephorus had embroidered onto his story, but current thought is that this comet may have been one of the "sungazers," in which case such a splitting is quite plausible.





Interestingly, Aristotle and Seneca represent the opposing points of view in the millennia-long debate over whether comets were atmospheric or celestial phenomena. Aristotle held the view that comets were vapors from the ground that slowly burned in the upper air; they were associated with dry and windy weather and were apparently caused by that weather rather than affecting it. He cites the great comet of 371 B.C. as a proof of his idea, for that winter was dry with prevailing north winds. In the same year, an earthquake and tidal wave also occurred, and Aristotle held that the tidal wave was caused by the strong winds. He also connected the appearance of a notable comet in 340-341 B.C. with a storm that broke out in Corinth.

Seneca rejected some of Aristotle's logic and argued that comets must be objects farther away than the Moon. This was, of course, little more than a lucky guess, such as had apparently been made far earlier by Chaldean sky-watchers. It is Seneca who provided us with what we do know about Chaldean ideas on comets.

Seneca passes on to us two different Chaldean views: one reported by Apollonius of Myndus and one by Epigenes — both of whom claimed to have studied among the Chaldeans. The latter stated that the Chaldeans thought comets were "fires produced by a kind of eddy of violently rotating air." But Apollonius reported a Chaldean opinion — remarkably on target! — that comets are like planets, yet are invisible most of the time because they are too far from Earth.

Pliny the Elder agreed with Aristotle's opinion that comets were atmospheric phenomena and described 12 different kinds of comets based solely on their appearance or resemblance to earthly objects. The comets called Cerastias had the form of a horn, Hippias of a horse's mane, and Lampadias of a burning torch. According to astronomer David W. Hughes, the term Lampadias was used to describe a comet viewed in 530 A.D. We will be seeing that same comet, now called Halley, in just a few months.

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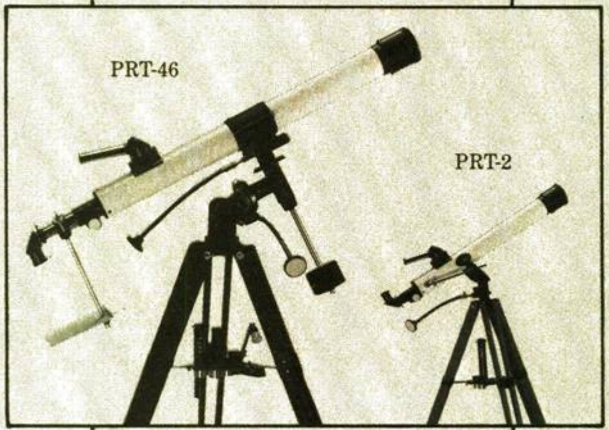

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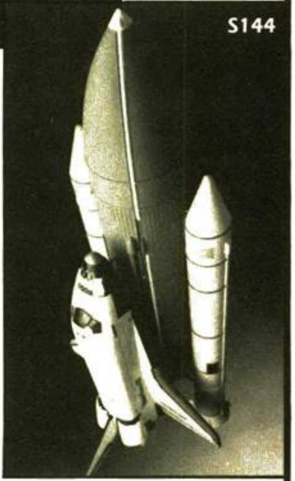

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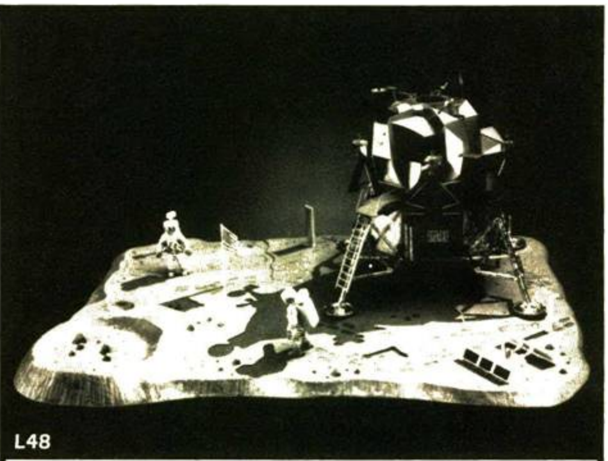

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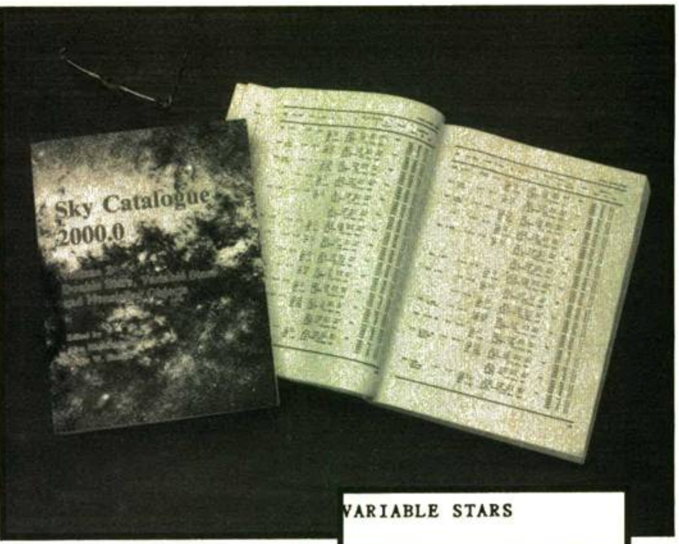
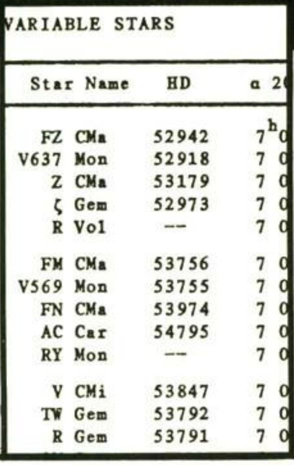
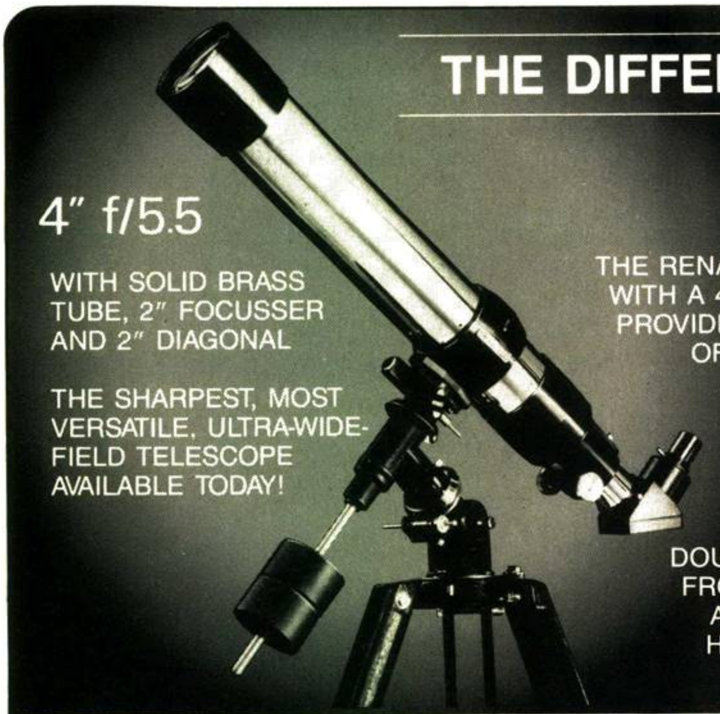




ARIABLE STARS

Star Name	HD	α 2
FZ CMa	52942	7^h
V637 Mon	52918	7
Z CMa	53179	7
ζ Gem	52973	7
R Vol	--	7
FM CMa	53756	7
V569 Mon	53755	7
FN CMa	53974	7
AC Car	54795	7
RY Mon	--	7
V CMi	53847	7
TW Gem	53792	7
R Gem	53791	7



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ASTROPHOTO OF THE MONTH

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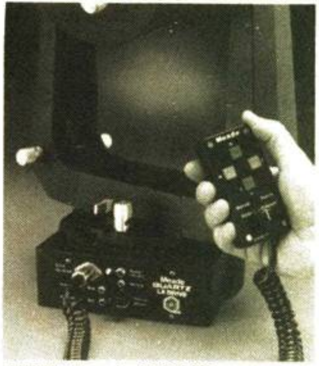

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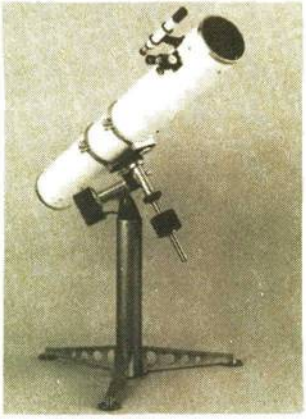

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Much Ado About 0.1mm

Photography in Astronomy

by
Barry Gordon

In an ordinary photograph, the size of an image is proportional to the focal length of the camera lens which recorded it. But in astrophotography, this isn't always the case. Stars are so distant that even the longest focal lengths record them only as points, which have no image size at all. In fact, a point source is defined as "any object whose image size is not directly proportional to focal length."

In astrophotography we don't care about an object's actual size, but rather its apparent size — which is inversely proportional to its distance. In turn, we don't care as much about an object's apparent size as its image size on film — which is determined by both apparent size and the camera's focal length.

But point sources — stars — do not necessarily form point images on film. A look at any astrophoto shows that different stars have different size images. The image size of an object on film depends on a number of factors, including a star's brightness and exposure time. The key is that image size is not directly proportional to focal length. Generalizations like "stars are point sources and planets are extended objects" are not always true. For backyard telescopes, both Pluto and Betelgeuse are point sources; but when photographed under the best seeing conditions with a large observatory instrument, both have visible disks.

You may be asking, "Why would anyone care if Pluto is a point source or shows a disk?" In astrophotography, this information is necessary because exposures for point sources must be handled differently than those for extended objects. Since point source images are independent of focal length, exposures of stars depend upon aperture and not focal ratio. (Focal ratio is simply focal length divided by its aperture.) But for objects larger than stars, proper exposures *do* depend on focal ratios, so it is important to recognize when to treat objects as point sources and when not to.

In this photo of a planetary conjunction, the Moon and nearby Venus appear fundamentally different; one records on film as a point source, the other as an extended object. This dissimilarity affects the exposure time for each object. Photo by Frank Zullo.

For quite some time, photographers have known that the elements of a photographic exposure — an object's brightness, film speed, exposure duration, and lens speed — can be tied together using the equation:

$$B \times S \times e = f^2$$

where S = the film's speed, or ISO rating, e = exposure duration in seconds, f = focal ratio of the lens, and B = brightness factor. This brightness factor is an empirically-derived value representing the surface brightness of a given sky object. If you know the B value for the sky object you want to photograph, you can now use a little arithmetic to work out the best exposure time . . . for extended objects. For example, let's say you want to take a picture of the Full Moon using an f/10 optical system and ISO 100 film. The brightness value for the Full Moon is 125 (see table on page 54), so the exposure should be:

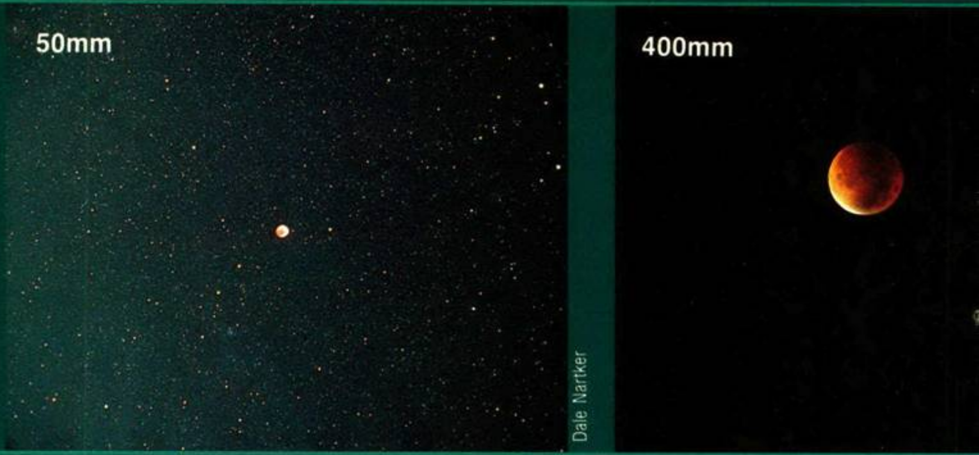
$$125 \times 100 \times e = 10^2$$

Solving for e:

$$e = \tfrac{1}{125} \text{ second}$$

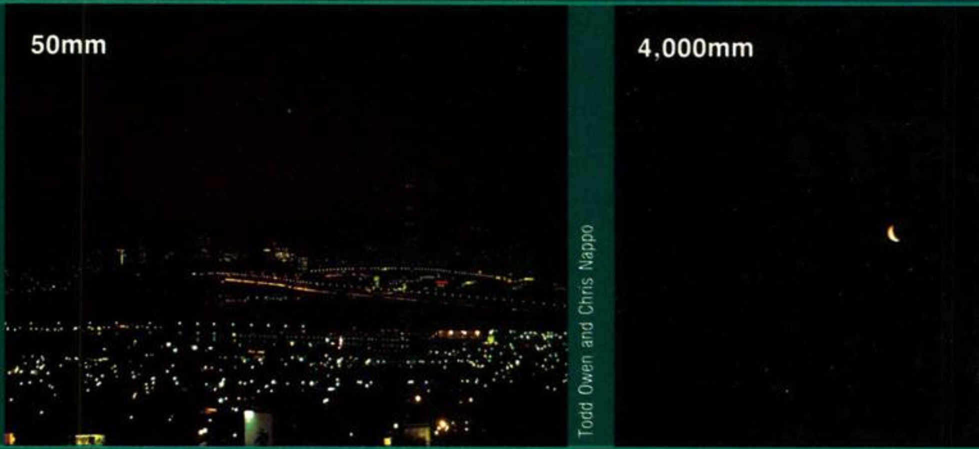
But what about point sources? The problem, as we mentioned previously, is that focal ratio has no bearing on point sources. Instead we must consider

Objects in the solar system appear to grow in size when photographed with increasing focal lengths. At 50mm, the Moon is devoid of detail, but at 400mm its maria are clearly visible. Photographed at the prime focus of a typical Schmidt-Cassegrain (2,000mm), the result is an impressive Full Moon portrait. The longest focal length shows only a tiny portion of the Moon's disk surrounding the crater Plato. As focal lengths increase, so must exposure times to provide equal image density.



Dale Nartker

Planets are much smaller than the Moon: at 50mm, Venus is a point source and long exposures merely oversaturate its image. A 4,000mm system clearly shows its disk, while a 12,000mm focal length clearly records Venus as a subtle crescent. An eyepiece projection system of 40,000mm focal length results in an impressive, large crescent.



Todd Owen and Chris Nappo

aperture which we'll call "a." The brightness factor, B, has no bearing on a point source either, since it is essentially the same as a star's magnitude. So instead of using B in the equation, we'll substitute M for magnitude. We'll need a new equation:

$$S \times e \times a^2 = 10^{0.4(M+13)}$$

Even though this new version is more complex than our original formula, it *is* handy for calculating exposure settings for stars. Using ISO 100 film, let's see how long we'll need to expose in order to photograph a second-magnitude star with a wide-open 50mm f/2 lens. The first thing we need to determine is the absolute aperture of the lens — this is merely the focal length divided by the focal ratio. Our absolute aperture is 50/2 = 25mm. Plugging this into the equation gives us:

$$100 \times e \times 25^2 = 10^{0.4(2+13)}$$

or

$$100 \times e \times 625 = 10^6$$

By solving the equation for e, we find our exposure time is 16 seconds. That f/2 lens "speed" applies strictly to recording extended objects, where short focal length compensates for small aperture by packing modest amounts of light into small, bright images. For point sources, it is not a fast f/2 lens — it is merely a small 25mm aperture.

We now know that stars act like point sources, and most other sky objects — including the sky brightness background itself — act like extended objects. This wraps things up fairly well, except for pesky switch hitters. The planets, you see, insist on having it both ways.

Despite actually being a point *source*, a star does not produce a point image. Image size depends upon film resolution, lens type, and the very nature of light itself. Film resolution is linked to the size of the emulsion grain — the bits of silver halide that record the image — and varies greatly from film to film. Light itself creates what's known as a diffraction disk. This is the smallest possible image of a point source that can be formed by parallel light rays passing through an aperture. In other words, the diffraction disk is the image of a true point at an infinite distance, formed by a perfect lens with no aberrations. But diffraction is not the only problem. Atmospheric turbulence and light scattering in the film, all expand the image of point sources. This places a lower limit on the size of the image we can form on film.

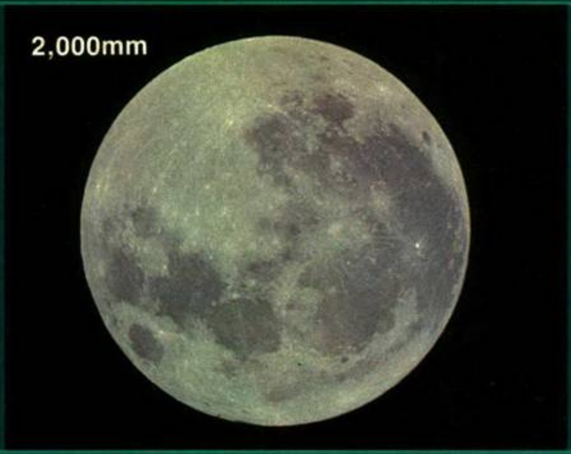
If we start with a specific focal length for an extended object and then decrease the focal length, we'll decrease the image size. If we keep decreasing the image size, we eventually arrive at a lower limit called the threshold image size. Once reached, this will remain constant — even if we keep decreasing the focal length. This threshold image size is the dividing line between point sources and extended objects.

Based on my own experience, I've found that 0.1mm is a pretty good value for threshold image size. Therefore, when standard equations for finding image size:

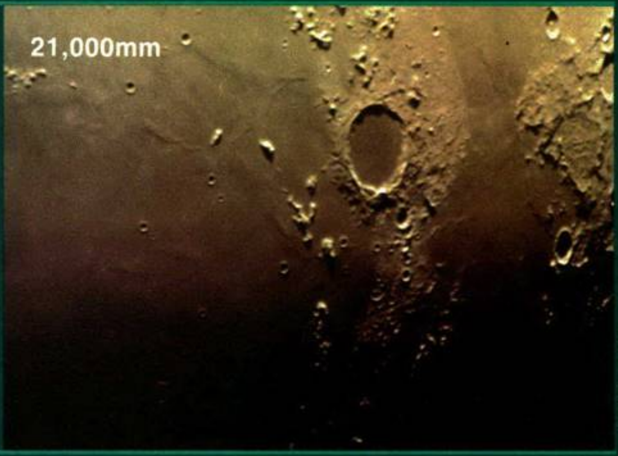
$$\textit{image size} = F \times (S°/57.3)$$

start giving values below 0.1mm, forget

Michael Barrett


2,000mm

Alan Dyer


21,000mm

Jean Dragesco

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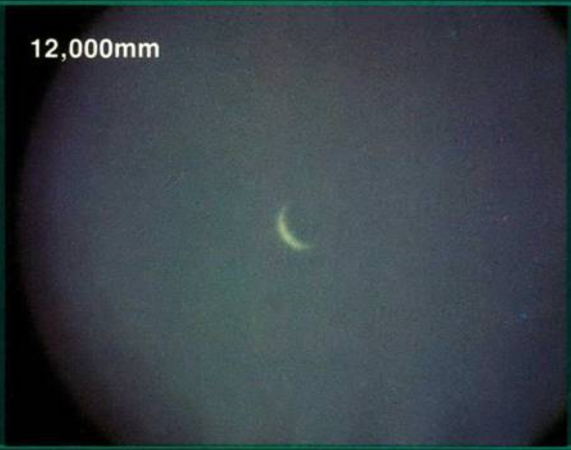
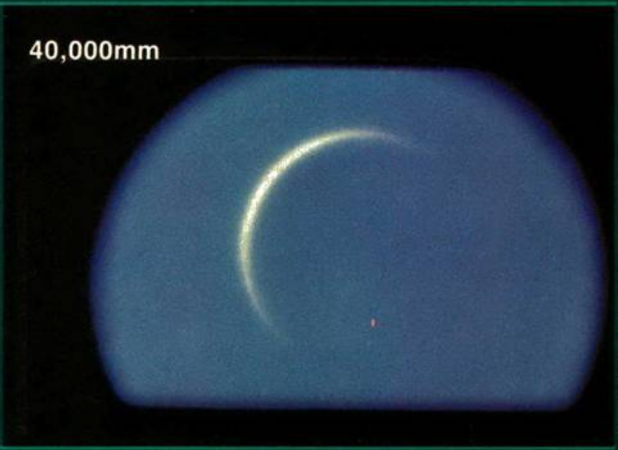

12,000mm

Fred Espenak


40,000mm

Charles F. Capen

about image size and start treating your subject as a point source. (Note that S° is the size in degrees, and F is the focal length. Don't confuse F, the focal length, with f, the focal ratio.)

The major planets all have apparent sizes which cross the 0.1mm image size threshold within the range of focal lengths commonly used by astrophotographers. So when photographing planets, first find out whether the object will be a point source or a disk, then use an equation to find your exposure time.

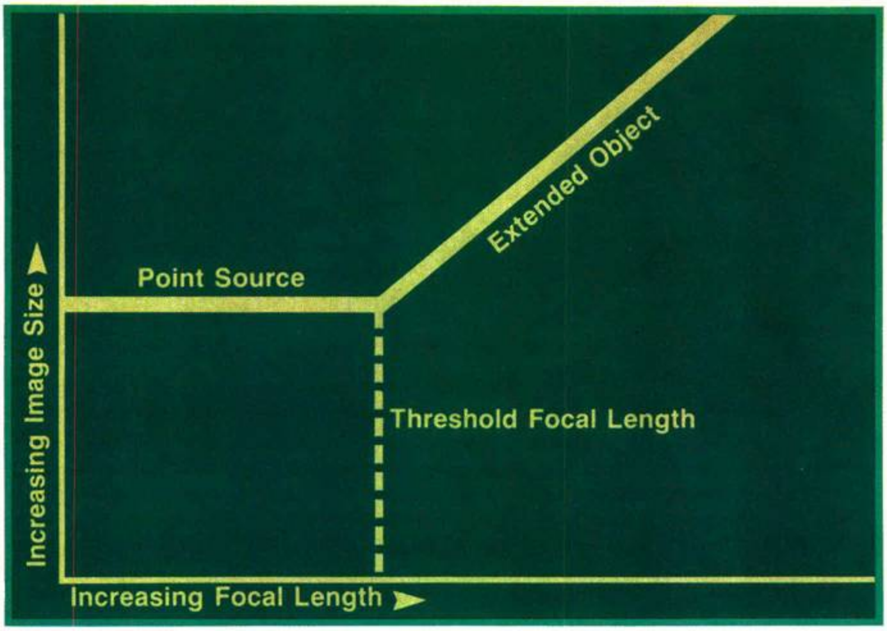
Things get even more tangled when considering conjunctions or occultations. This type of astrophotography is the most complex of all. The Moon, for instance,

Use this table to determine at what focal length various objects — together in a single frame — will be correctly exposed. Imagine you want to take a picture of Jupiter and the Gibbous Moon: scanning the columns shows you that the "ideal" focal length for these two objects is 1200mm.

Focal Length at Which Extended Object and Point Source Have Equal Image Brightness

Extended Objects		Venus	Mercury	Full Moon	Gibbous Moon	Mars Jupiter Quarter Moon	Crescent Moon	Saturn
Point Sources	B	1,000	250	125	60	30	15	5.7
	M							
	−4						240	
Venus								
	−3						390	
Jupiter	−2	5,000	2,500	1,800	1,200	870	610	
Mercury	−1	7,900	4,000	2,800	1,900	1,400	970	
Mars								
	0	13,000	6,300	4,500	3,100	2,200	1,500	1,000
Saturn								
	1	20,000	10,000	7,100	4,900	3,500	2,400	1,500
	2	32,000	16,000	11,000	7,700	5,500	3,900	2,400
	3	50,000	25,000	18,000	12,000	8,700	6,100	3,800
	4		40,000	28,000	19,000	14,000	9,700	6,000
	5			45,000	31,000	22,000	15,000	10,000
	6				49,000	35,000	24,000	15,000

Key: M = Magnitude; B = Brightness Factor



This diagram illustrates the relationship between a telescope's focal length and the size of an image it produces on film. Point sources — stars — hold a constant image size regardless of focal length. Extended objects appear as point sources until a threshold focal length is reached, whereafter their image size proportionally increases with focal length.

Point Source vs. Extended Object Threshold Image Size

	B	M	F	A	s
Sun	50,000,000	−26.7	13	1920	0.12
Moon	125	−12.7	13	1865	0.12
Mercury, at Superior Conjunction	250	−1.7	2877	4.7	0.07
Venus, at Superior Conjunction	1000	−3.3	2754	9.9	0.13
Mars, at Opposition	30	−1.7	997	17.8	0.09
Mars, at Conjunction	30	2	5477	3.5	0.09
Jupiter, at Opposition	30	−2.7	629	46.8	0.14
Jupiter, at Conjunction	30	−1.4	1144	30.5	0.17
Saturn, Rings Edge–on	5.7	0.67	1294	19.4	0.12
Uranus	3	5.5	8681	3.9	0.16
Neptune	0.5	7.8	10221	2.3	0.11

Based upon Focal Length at which Point Source and Extended Object have equal Image Brightness

B = Brightness Factor
M = Magnitude
F = Focal Length in mm
A = Apparent Angular Size in Arc-seconds
s = Image Size in mm

This table provides information for making exposures of both point sources and extended objects in the same field of view. At an image size of about 0.1mm, stars and planets can be correctly exposed in a single frame (see text).

almost always acts like an extended object; a star always acts like a point source; and a planet can go either way, depending upon focal length. It's simple when both objects are point sources — merely treat the event as a starfield. But in rare cases, like lunar occultations of Venus, both objects may be extended. More commonly, though, one object is a point source and the other is extended.

Estimating the exposure for each individual object is easy to do. But how do you correctly expose each object in the same field of view? The way to control the situation is focal length. With all else fixed, increased focal length dims the image of the extended object while leaving that of the point source unchanged. Because many conjunctions involve a brilliant Moon alongside a dimmer star, long-focus lenses are definitely the order of the day — or night.

To begin, determine the focal length required to equalize the exposure for both the extended object and the point source object (see table). For example, suppose you're lucky enough to witness one of those spectacular occultations of Venus by the crescent Moon. If you want a generous image size, and pick a lens with a focal length in the 1000mm neighborhood, then you'll be dealing with two extended objects — and you'll have to settle for either an overexposed image of Venus or an underexposed Moon. However, if you want to equalize exposures for the two objects, a lens around 300mm in focal length — which would make Venus a point source — would be ideal. To balance an exposure with Jupiter as an extended object occulting a second-magnitude star, you'd need a focal length on the order of 5,500mm, and to capture an occultation of a fifth-magnitude star by a Full Moon, you'd want a focal length in the neighborhood of 45,000mm.

The values listed in the adjacent table come from a theoretical formula where the focal length, F, balances the exposure for a point source of magnitude M with that of an extended object having the brightness factor B. This formula is derived by assuming we want to photograph a point source and an extended object at the same time. Using this information, we can rewrite our previous equations as:

$$S \times e = f^2/B$$

and

$$S \times e = 10^{0.4(M + 13)}/a^2$$

Since we are considering one photograph, the values of S and e must be the same in each equation. Consequently, the right sides of the two equations are equal, so that:

$$f^2/B = 10^{0.4(M + 13)}/a^2$$

or

$$f^2 \times a^2 = B \times 10^{0.4(M + 13)}$$

and because $f = F/a$:

$$F = \mathrm{sqrt}(B) \times 10^{0.2(M + 13)}$$

Armed with this formula, we can now take astrophotos of point and extended sources with confidence. It all comes down to a fairly simple rule: if your image size formula equals larger than 0.1mm, then you're photographing an extended object. If the image size falls below 0.1mm, disregard it — you're dealing with a point source. And if you get an image size right around 0.1mm, call it what you will — it really doesn't matter.

This article is adapted from Astrophotography, *a book published by Barry Gordon in 1983. A revised and expanded second edition will be published by Willmann-Bell in mid-1985.*

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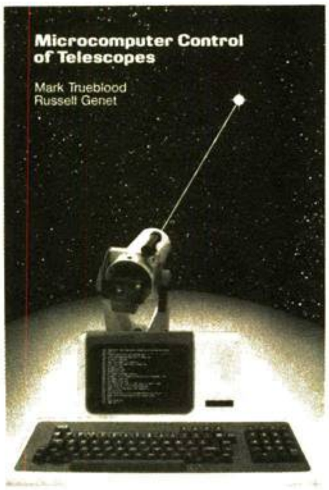
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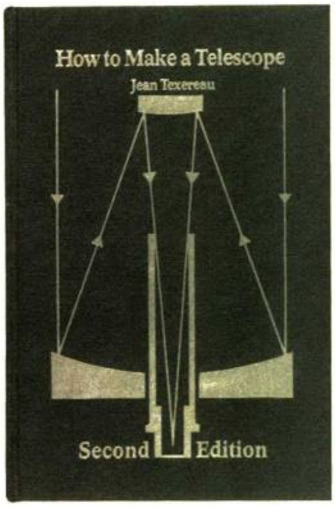
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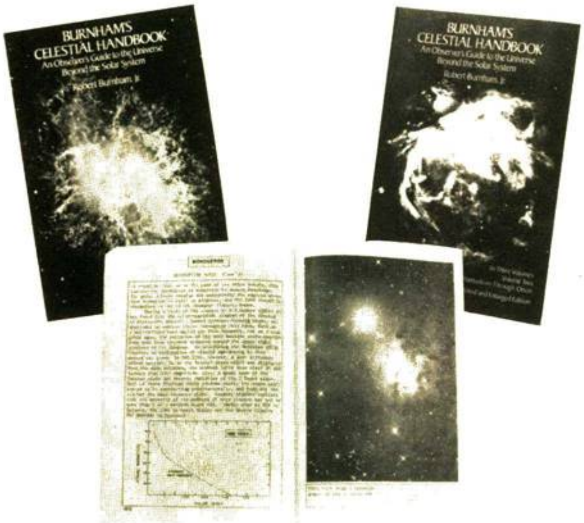
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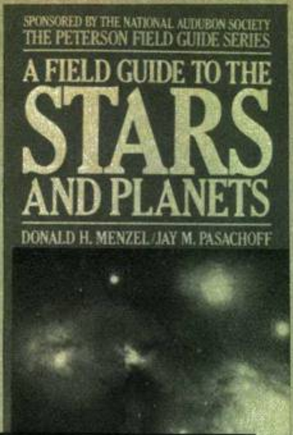
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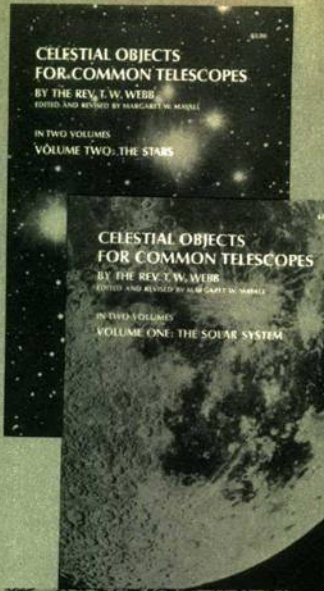
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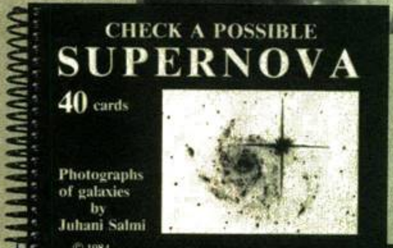
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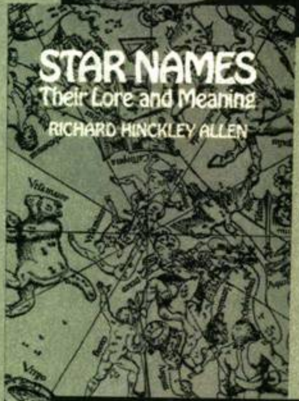
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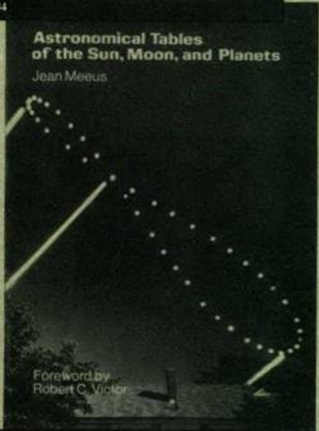
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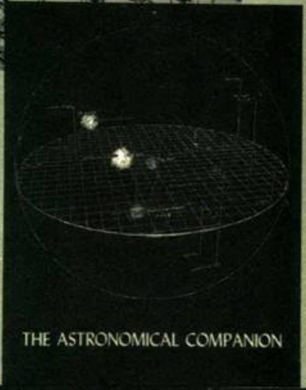
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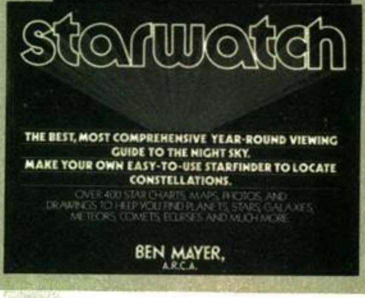
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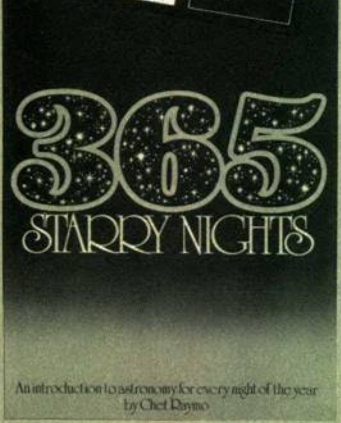
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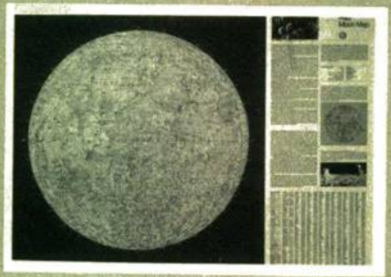

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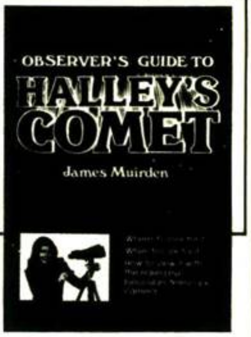

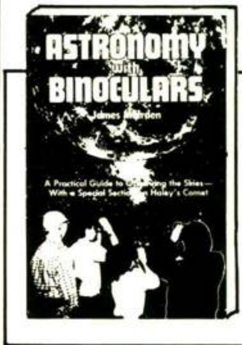
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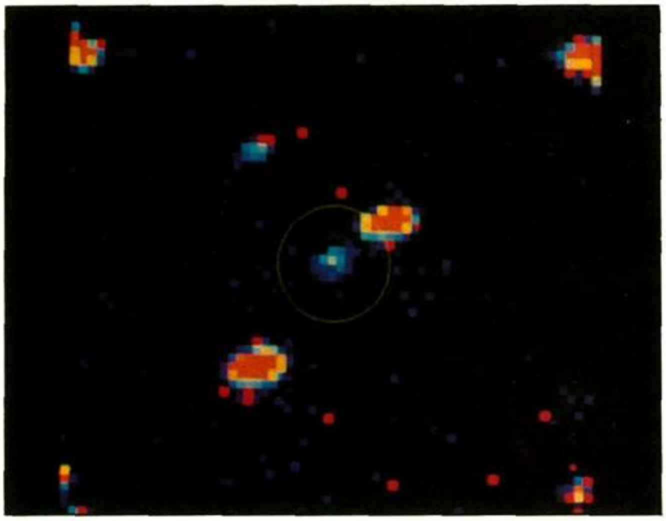


Rudolph Schild of the Smithsonian Astrophysical Observatory took two 2-minute exposures of Halley's Comet on the night of February 16, 1985, using the 24-inch reflector at the Whipple Observatory in southern Arizona. The comet (inside the circle) was at 18th magnitude; the asymmetry of the comet's image shows that a coma has probably begun to form and that it is not completely spherical around the nucleus. (The telescope tracked on the comet, so the background stars are trailed slightly.) SAO photo.

When Galaxies Collide

Normal spiral galaxies are relatively stable and quiet entities — they tend to mind their own business. But when two galaxies pass close by each other, or actually collide, their centers undergo a fierce awakening that rocks them for millions of years.

This scenario was recently proposed by a team of American and European astronomers to explain the inner workings of galaxies "in trouble" — those which are experiencing a disturbance within their nuclei and consequently send off huge amounts of visible, radio, X-ray, and gamma-ray radiation. This high-energy radiation is indicative of gas clouds being compressed into rapid star formation.

The astronomers — William Keel of the National Optical Astronomical Observatories (NOAO), Robert Kennicutt Jr. of the University of Minnesota, E. Hummel of the Max Planck Institute in West Germany, and J.M. van der Hulst of the Westerbork Radio Observatory in the Netherlands — propose that the causes of galaxy interaction are complex and varied. For example, sharp increases in star formation at or near a disturbed galaxy's nucleus result from galaxy-wide disturbances and the redistribution of interstellar gas within the galaxy. The powerful radiation from a disturbed galaxy's nucleus, however, seems to occur because of tidal forces from the intruding galaxy.

The high-energy radiation in "victim" galaxies is probably only temporary. Says Keel, "Feeding the monster only happens for so long. The conventional view was that the more disturbed the system was, the more gas would go into the core, and the more radiative activity one would find at the nucleus. But this holds only to a point. Either they eat all the gas they can get or the distortion of the galaxy spreads things out so that the gas is more difficult to get."

This refined view of galaxy encounters comes from a sample of 161 nuclei in galaxies which appear to be interacting, as compared with a similar number of lone galaxies. "We tried to select a set of galaxies so close together — four or five galactic radii — there was reason to believe they were bound," says Keel. "The differences between them and the isolated, field galaxies would have to be the result of interaction. We concentrated on the nucleus because it can respond to a tidal perturbation about a hundred times faster than the disk can. That makes the nucleus a sensitive tracker of interaction effects."

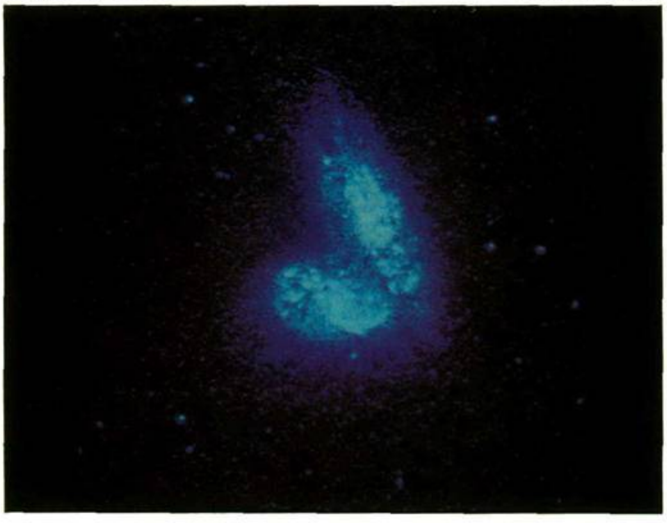
Based on these comparisons, the astronomers offer the following insights into close encounters between two galaxies:

- As galaxies pass within about 8 to 10 galactic diameters of each other, each begins to experience tidal forces exerted by the other's gravitational field. "The forces are weak, but they operate over hundreds of millions of years," says Keel.
- The intricate, gravity-controlled arrangement of moving mass within the galaxies is disrupted by the intruding gravitational field, causing gas clouds formerly in stable orbits to collide with increasing frequency. Such collisions increase the density of the outer shell of the nucleus and feed galactic gas inward toward the drowsing "monster" at the core.
- Changes in the nucleus occur on a time scale of some five million years for the inner kiloparsec of the galaxy. On a longer time scale, as the galaxies slowly pass near — or sometimes through — each other, changes begin to appear in other parts of the galaxies. A shredding and stretching of spiral arms, deformed orbits, and other distortions which can be observed directly are evidence that passing galaxies do, in fact, interact with each other. These distortions are normally visible only after perigalacticon — the point of closest approach — and occur over a period of perhaps 500 million years.
- At the nuclei of the galaxies, rising tidal forces increase star formation, often in the form of a "starburst," in which the nuclei contain some 20 to 30 times as many young stars as normally found in an entire galaxy. As Keel puts it, "It looks as if you put tens of thousands of Orion Nebulae on top of one another." Starbursts seem to occur almost exclusively among interacting galaxies, in fact, and more than 20 percent of observed starbursts are in close pairs of galaxies. According to the astronomers, the amount of enhanced star formation increases with the brightness of the galaxy, suggesting that "tidal effects act as a trigger as well as a direct cause" in accelerating the birth rate of stars.
- The output of radiation in the galaxies' nuclei erupts into the kind of brightness associated with Seyfert galaxies — after quasars, the most luminous objects in the universe. The astronomers write, "One of the most striking results of this study is the higher incidence of Seyfert nuclei in certain classes of interacting systems." The incidence of Seyferts in this survey is three times that predicted by observing the isolated galaxies, and may be still higher — abundant young hot stars in the centers of disrupted galaxies could hide Seyfert nuclei. The astronomers report that this high incidence of Seyfert nuclei, ". . . and the tendency for Seyferts to occur in closer-than-average pairs, are our strongest indications that nuclear activity can be produced by galaxy interactions."
- Once the inflamed nucleus has gorged itself on gas from the disk, it either consumes all the easily-available material or drops to such a low level of activity that it's easily concealed by the bright young stars around it. In any event, the astronomers report, the relative abundance of Seyfert nuclei among interacting galaxies appears to be matched by a relative dearth of them in galaxies after interaction ceases, suggesting that the Seyferts are kindled by the interaction, and then starved back to inactivity when the troubled galaxy returns to normal.

As grand as these events might seem, they would be largely masked to a resident of an interacting galaxy.

NGC-4567/NGC-4568

Laird A. Thompson



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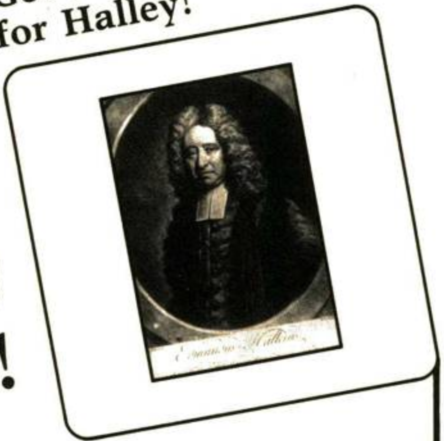

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Dear Rodger,

As you know, I've been working with apochromatic refractor designs for several years and finally found a lens recipe that didn't cost megabucks to make. Refractive indices, radii, thicknesses were further refined by computer to 80mm x 500mm.

Well, I just got the first O.G. test set made up, mounted, baffled and collimated. An NBS test chart was secured at 250 ft. and flawless, colorfree images were observed to 150x (8mm Brandon and 2.4x Dakin Barlow).

I then located the Dakin in front of the 90° prism calibrated at 5x and again perfect resolution all the way to 312x. Next I added another Dakin 2.4x back on top of the prism. So help me, I stood there in amazement using the 16, 12 and 8mm Brandons up to 750x. Rodger — no color whatsoever and still a razor sharp flat image to the extreme edge of field!

*Then — I know this is crazy — I put **another** 2.4x Dakin inside the one atop the prism. I'm up to an effective 14,400mm focal length. The 16mm Brandon is still perfect. The 12mm is also perfect! I'm at 1,200x and can't break down the image.*

*I fumble and nearly drop the 8mm Brandon. It can't be, but it is! I've got **sharp, color free test lines at 1,800x!** I'm hysterical with ecstacy! This is unheard of! What a lens, what a fantastic set of glass! With those 3 Barlows, the f/6.25 triplet is now f/180, a focal length of over 47 ft.*

*Rodger, I've been telescoping all my life ever since my folks bought me a 3" Skyscope at age seven, and have never experienced anything like this. Were this fast f/6.25 system an achromat, we'd be in big trouble at 180x. This animal exceeded that by **ten times** and still sharp, no color.*

I'm still in shock and can't wait until you and your weekend observing group can see this apochromat for yourselves.

Best regards,
Don V. Yeier

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According to Keel, "For [our Galaxy] to have a strong interaction, the culprit would have to be about four times closer than Andromeda (some 670 kiloparsecs away). If a monster woke up at the center of the Milky Way, and if we could see through the dust that hides the nucleus from us, it would look something like Jupiter seen against a stellar background. A very bright star." But the star formation triggered by the interaction would be more extensive, notably increasing the number of young bright stars and emission nebulae visible in the night sky. In a stately manner, our Galaxy would enter — in astronomical terms — a moment of dynamic chaos.

The astronomers took spectroscopic measurements between 3700 to 6900 Angstroms — roughly the optical region between violet and deep red — of the 161 interacting nuclei in attempts to measure their content. By analyzing the wavelengths of light emitted by the gas, the astronomers inferred gas temperatures, compositions, and motions, as well as the source of radiated energy. Images made with special filters tuned to emissions of hydrogen gas, taken with an image-intensifier camera, were used to localize the effects of galactic interaction, and to trace the extent and structure of the gas in the galactic nuclei.

On November 13, 1984, at about 8:00 p.m. Mountain Time, Arizona amateur astronomer David Levy found a fuzzy object in Aquila. The object, located next to open star cluster NGC-6709 at 18h47m, +9° (1950), appeared nebulous but soon moved — after 917 hours of searching during 19 years, Levy had discovered a comet. The following day, the object was spotted by Massachusetts observer Michael Rudenko. The new comet — 1984t — was designated Comet Levy-Rudenko. Comet 1984t shone at magnitude 9 when discovered, but quickly brightened to magnitude 7.5 as it moved northward toward the circumpolar constellation Ursa Major. One of the brightest comets in recent years, Levy-Rudenko was observed by many backyard astronomers until fading in spring 1985. Although it is now dim — around 15th magnitude — Comet Levy-Rudenko can still be photographed by patient astrophotographers with large telescopes. Its epoch 2000 positions for June are: 9h10.3m, +4°58.9′ (the 10th), and 9h19.5m, +3°18.9′ (the 20th). This picture of Comet Levy-Rudenko was taken on November 26.99 UT by John Glaspey and Rene Racine, with the 1.6-meter telescope at Mont Megantic Observatory in Quebec.

Pluto/Charon Eclipses Begin

Pluto and its satellite Charon have begun eclipsing one another, giving astronomers the opportunity to learn a great deal more about this tiny, distant planet and its companion.

Richard Binzel, a graduate student at the University of Texas at Austin, obtained the first definitive eclipse observation on February 17 using a 36-inch McDonald Observatory telescope. Binzel's detection was confirmed on February 20 by Dr. David Tholen, an astronomer at the University of Hawaii, from Mauna Kea. A similar observation was made on January 16 by Edward Tedesco at Palomar Observatory, but was not considered definitive.

Pluto's moon, Charon, was discovered in 1978 by James Christy at the U.S. Naval Observatory when he noticed that the planet's images appeared slightly elongated on photographs (see "Mysterious Pluto," ASTRONOMY, July 1980). The mutual eclipses of the planet and its satellite were predicted soon after Charon's orbit was determined. Astronomers predicted that observable eclipses would begin in 1982 or shortly thereafter. Eclipses occur for a five to eight year period every 124 years.

Binzel, who recently had asteroid 2873 Binzel named for him in recognition of his observations of the light curves of asteroids, was working as a summer student at the Naval Observatory in 1978 when Christy discovered Charon.

The eclipsing consists of alternating transits of Pluto by Charon with occultations of Charon by Pluto. During these events, the total brightness of the system changes slightly — some 0.04 magnitude at present — for about two hours. Because the Pluto-Charon system has a period of 6d 9h 18m, events occur at roughly 3.2-day intervals. Astronomers will use the light curves to find accurate diameters for both Pluto and Charon. Currently, neither is known with any certainty.

Oddly enough, the International Astronomical Union has not officially recognized Charon (though most astronomers agree that it is real) because a direct photographic image of the satellite hasn't yet been obtained. The eclipse and occultation observations will make Charon official.

Binzel and Tholen coordinated their observation schedule so they could monitor Pluto continuously for an eight-hour period. However, the eclipse occurred at a time when the planet could be viewed only from Texas. Tholen's observation confirming the eclipse events came three nights later.

Binzel said the first eclipses in the series are shallow — that is, Charon appears to skim over the "top edge" of Pluto. But as the series continues, the viewing geometry changes, so that Charon eventually moves directly across the center of the planet.

"By observing changes in the shapes of the eclipse light curves over the next few years, we'll be able to determine accurate parameters for the size of the satellite and the size of Pluto," said Binzel.

Researchers suspect that Pluto has lighter and darker areas or spots on its surface. They plan to compare the light curves that would be produced if Pluto were a uniformly bright object with those actually observed. From the differences in the light curves, they can then infer the distribution of brightness on the surface of the planet.

"This will probably be our only chance to map the surface of Pluto during this century since there are at present no plans to send a spacecraft to Pluto," Binzel added.

Binzel has been looking for eclipses since 1982. During the past three years, he has made a deliberate study of Pluto's brightness, which varies throughout the course of its rotation. "We have tried to determine what Pluto's brightness changes are, so that if we saw an eclipse we could make sure that it really was an eclipse between Pluto and its satellite — not something due to the rotation of Pluto," he said.

Humans Still the "Ultimate Robots"

For years, a debate has raged about the extent of automation required in space. Some have proposed that man isn't needed for exploration beyond the upper atmospheric limits of Earth because high-technology machines can do just as well, if not better. But findings from a recent study at NASA's Marshall Space Flight Center in Huntsville, Alabama, show that human beings are essential in space, especially for activities which require creative thinking, analysis, planning, and fine motor skills.

Titled "The Human Role in Space" (THURIS), the study is under the management of Stephen B. Hall, a human factors engineer experienced in man/machine issues regarding complex space systems. "The THURIS study gives us a unified picture of how people and machines will work together in orbit or on planetary missions," said Hall.

For the study, engineers sifted through thousands of known facts and projected tasks expected of men and women in future missions. They then reduced this data to 37 generic jobs people could do in space. The tasks include removing and replacing protective coverings around spacecraft, surgically acquiring tissue samples, measuring physical dimensions of objects, and compensating for tracking errors in fine guidance systems.

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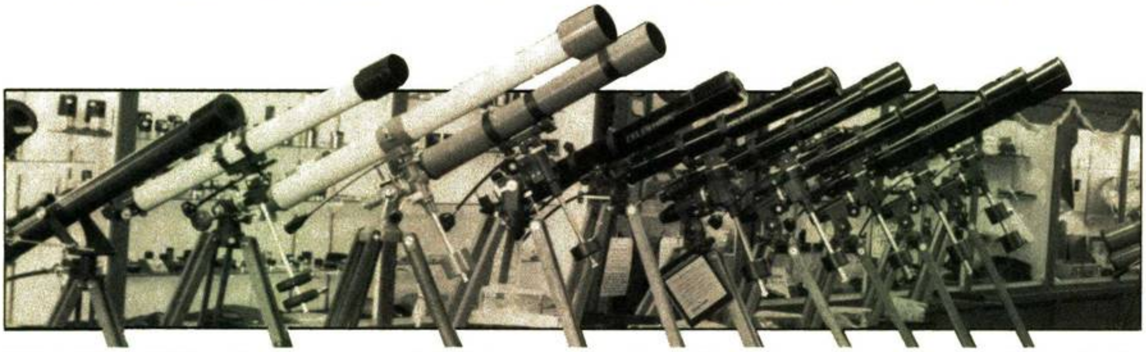

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ASTRO NEWS

criteria to help system designers decide how man should be involved. "For task allocation, we looked at the performance time, the relative cost, and the technological risk," said Hall.

The study next analyzed how much each of the generic tasks would benefit from human involvement. "The human being, of course, is the ultimate 'robot'," said Hall, "and his range of capabilities are tremendous — the ability to recognize different objects, for instance, to feel shapes and textures, and to discriminate odors. He has cognition, memory, and so many other capabilities that you couldn't possibly tap all the ones he has.

"Additionally," Hall continued, "we were analyzing human limitations — for example, we can't calculate at a high rate like machines, such as those that can compute an orbital trajectory many times a second. This doesn't mean man should be replaced by machines. We do, however, need to understand our capabilities compared to machines in order to use them effectively. They can complement and amplify human capabilities, and liberate us from repetitive, routine tasks. They can free us to imagine and to explore new horizons."

ASTRO CALENDAR

June 7-8
15th Annual Apollo Rendezvous and Telescope Fair, Dayton, Ohio. Contact: Chairman, Apollo Rendezvous, P.O. Box 20268, Dabel Branch, Dayton, OH 45420.

June 9-12
Southeastern Planetarium Association Annual Conference (professional conference), Land Between the Lakes, Kentucky. Contact: Doug Gegen, Visitor Center, Land Between the Lakes-TVA, Golden Pond, KY 42231. Phone (502) 924-5602.

June 17
3rd American Workshop on Cometary Astronomy, Tucson, Arizona. Contact: Steve Edberg, Jet Propulsion Laboratory, 4800 Oak Grove Dr., T-1166, Pasadena, CA 91109.

June 17-22
ALCON '85, Tucson, Arizona. Contact: Shelley Fleischman, c/o Venture Travel Inc., 6709 E. Camino Principal, Tucson, AZ 85715.

June 22-27
97th Annual Meeting of the Astronomical Society of the Pacific, Northern Arizona University, Flagstaff, Arizona. Contact: Andrew Fraknoi, Summer Meeting, A.S.P., 1290 - 24th Ave., San Francisco, CA 94122. Phone (415) 661-8660.

June 28-30
IAPPP Summer Workshop, Flagstaff, Arizona. Contact: Robert Fried, Braeside Observatory, P.O. Box 906, Flagstaff, AZ 86002. Phone (602) 774-1249.

June 28-July 1
Royal Astronomical Society of Canada General Assembly, Edmonton, Alberta, Canada. Contact: RASC, Edmonton Centre, c/o Edmonton Space Sciences Centre, 11211 - 142 St., Edmonton, Alberta, Canada T5M 4A1.

July 11-14
The Study of Variable Stars Using Small Telescopes (symposium), University of Toronto, Toronto, Ontario. Contact: Dr. John R. Percy, Department of Astronomy, University of Toronto, Toronto, Ontario, Canada M5S 1A1.

July 12-14
The Convention of the Mid-States Region of the Astronomical League, Wichita, Kansas. Contact: Mike Kittrell, c/o Crown Products Inc., 310 N. Wabash, Wichita, KS 67214. Phone (316) 267-1051 days or (316) 524-8392 evenings.

July 15-20
Spaceweek UPstate 85, Haywood Mall, Greenville, South Carolina. Contact: PAS, P.O. Box 197, Fair Play, SC 29643-0197.

July 15-24
International Space Week '85, Cocoa, Florida. Contact: James B. Harris, Jr., Director, Florida Spaceweek Committee, 993 Macco Rd., Cocoa, FL 32927.

July 15-August 2
Astronomy Institute for Pre-College Teachers, The University of Texas at Austin, Austin, Texas. Contact: Mary Kay Hemenway, College of Natural Sciences, The University of Texas at Austin, Astronomy Department, RLM 15.308, Austin, TX 78712. Phone (512) 471-4461 ext. 307.

July 18-21
The Annual Convention of the North West Region Astronomical League, Spokane, Washington. Contact: Vern Slicter, W. 10903 19th St., Spokane, WA 99212.

July 22-26
1985 Summer Institute, sponsored by Spitz Space Systems, Inc. Contact: Mona E. Coldiron, 1985 Summer Institute, Spitz Space Systems, Inc., P.O. Box 198, Chadds Ford, PA 19317.

August 9-11
STARFEST '85, The River Place Campground, Mount Forest, Ontario, Canada. Contact: Andreas Gada, 145 St. George St., Apt. 701, Toronto, Ontario, Canada M5R 2M1

August 15-16
The New Vision of the Universe (international astronomical symposium), Medellin, Colombia. Contact: Kevin P. Marshall, F.R.A.S., President of ACAFA, Calle 56, N°47-23, Apto. 601, Medellin, Colombia, South America.

August 15-17
Mountain States Star Party, Monte Cristo Campground (40 miles east of Ogden), Utah. Contact: Bob Tillotson, 2336 W. 5650 South, Roy, UT 84067, phone (801) 773-8106 or Dennis Donnelly, 56 Tulane, Pocatello, ID 83201, phone (208) 232-4060.

August 15-19
Second Annual Mt. Kobau Star Party, Okanagan Valley, British Columbia, Canada. Contact: Peter Kuzel, 4100 25th Ave., Vernon, British Columbia, Canada V1T 1P4.

August 17
Stellafane, Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Rd., Sudbury, MA 01776.

September 13-15
Astrofest, Chicago, Illinois. Contact: Astrofest, P.O. Box 596-A, Tinley Park, IL 60477, or phone Jon Nehls at (312) 385-3473.

September 28
Ohio Turnpike Astronomers Association Convention, The University of Akron, Akron, Ohio. Contact: Philip Hegenderfer, 5070 Manchester Rd., Akron, OH 44319. Phone (216) 644-0230.

Meeting notices to appear in AstroCalendar must be submitted at least four months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

ANNOUNCEMENT — The Third Annual "Joy of the Universe" is underway. Programs are held the second Friday of each month at Lake Sebago Beach in the metropolitan New York area. For details, contact Joe Folmer, Secretary, Rockland Astronomy Club, 110 Pascack Rd., Pearl River, NY 10965. Phone (914) 735-4163.

ANNOUNCEMENT — The Arkansas-Oklahoma Astronomical Society invites all interested persons to the Sugar Loaf Star Fest on June 15th, to be held under the dark skies of the Sugar Loaf Mountains. For more information, contact Ross Kennedy, Route 3, Box 421-Y, Pocola, OK 74902.

ANNOUNCEMENT — The Texas Astronomical Society of Dallas invites all astronomy enthusiasts in the Dallas area to become members. Activities include monthly meetings, programs, and observing sessions. Contact Ron Price, 342 Kingsbridge, Garland, TX 75040. Phone (214) 530-0018.

ANNOUNCEMENT — The Astronomical Society of Ventura County meets the third Friday of each month, 7:30 p.m., at Santa Rosa School, Santa Rosa Rd., Camarillo, CA. The public is cordially invited to attend. Phone Hal Jandorf at (805) 529-3984 or Dennis Leatart at (805) 983-7598 for additional information.

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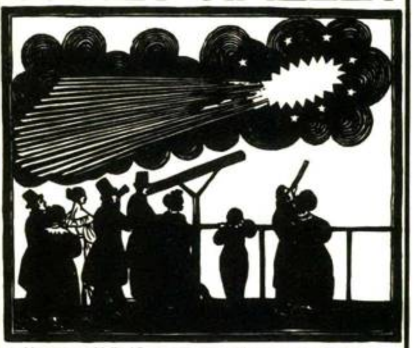

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The Anatomy of a Nebula

by
Ed Churchwell and
Kevin J. Anderson

A century ago, anything that looked fuzzy in a telescope and didn't go away when the eyepiece was cleaned was promptly dubbed a *nebula*. And that was that.

Life isn't so simple any more. In 1920, astronomers Harlow Shapley and Heber Curtis engaged in the so-called "Great Debate" over whether all nebulae lay within the Milky Way Galaxy or if some were actually distant galaxies themselves. Shapley lost that point — we now know that many of those fuzzy smears are other "island universes" like our own Milky Way.

But what about the real nebulae within our Galaxy? *Reflection nebulae*, such as those seen in and around the stars of the Pleiades, are dust clouds which scatter and reflect light from nearby stars. *Planetary nebulae*, such as the famous Dumbbell and Ring, are layers of stellar material cast off into space when a massive star undergoes convulsions in advanced age. *Emission nebulae* are probably the most spectacular of all — glowing pools of ionized gas and warm dust, lit up by hot stars embedded in them. Some of the sky's best showpieces, objects like the Orion and Lagoon nebulae, are emission nebulae.

Emission nebulae give off their own light rather than reflecting starlight. The gas in these glowing clouds typically stays at a temperature of around 8,000 Kelvins, heated by the ultraviolet radiation from nearby ionizing stars. Intense ultraviolet light from these nearby hot stars ionizes, or strips one or more electrons off, the hydrogen and other atoms in the nebula, leaving the parent atoms, now called ions, behind. Minus their electrons, the ions have a positive charge. In astronomical nomenclature, the chemical symbol followed by a Roman numeral indicates how many electrons have been removed from an atom. To complicate things, however, astronomers began naming ions with the Roman numeral II, rather than I. HI is a normal hydrogen atom with a full quota of one electron; HII is hydrogen minus one electron.

Emission nebulae — also known as HII regions — are a soup of electrons and hydrogen ions glowing brightly from the fluorescent radiation produced when these ions recombine with the free electrons. Atoms emit light at well-defined sets of wavelengths. Although our eyes are barely sensitive enough to detect it, photographic plates now reveal the vivid colors of the nebulae.

Since the days of visual observation, astronomers have studied diffuse nebulae with instruments of increasing sophistication. The most important of these is the spectroscope — a device that separates the wavelengths present in light. As early as 1864, William Huggins viewed the spectrum of the Orion Nebula and found that it contained spectral lines indicating the presence of gaseous hydrogen — rather than a broad continuum from stars or reflected starlight. Modern spectrographs now show the distinctive lines of many common elements.

Radio Nebulae

But nebulae emit more than light. Inside nebulae, liberated electrons interact with protons (hydrogen ions) to create radio radiation over a broad region of the spectrum. When radio astronomy came of age after World War II, astronomers found many strong sources of radio radiation inside the Milky Way, including HII regions. Since early radio maps of the sky suffered from poor resolution, astronomers often could not pinpoint exactly where the radio energy came from, so they couldn't tell what was doing the emitting. Even when the emitting object could be easily matched with its optical counterpart, the resolution was still so poor that little detail could be seen.

Advanced technology now allows astronomers a much closer look at nebulae — indeed, it allows them to look *inside* a nebula. This technique, called aperture synthesis, was developed in the 1960s. It enables radio astronomers to achieve substantially better resolution than is possible with the largest ground-based optical telescopes. By adding the signals of twenty-seven 85-foot telescopes spaced up to 35 kilometers apart, the Very Large Array (VLA) of the National Radio Astronomy Observatory achieves both high resolution (about 0.1 arc-second) and high sensitivity (see "Using Earth as a Radio Telescope," ASTRONOMY, October 1979).

Fronts and Shocks

The glowing HII regions we see are usually just the visible part of a much larger cloud of gas. The non-glowing gas is neutral (i.e., not ionized), cold, and often contains more than solitary atoms. Within the chilly confines of a molecular cloud, hydrogen atoms join to form hydrogen molecules — H_2. Cold, neutral clouds can be detected because molecules present in miniscule quantities — carbon monoxide, formaldehyde, ammonia, hydroxyl, water, and alcohol — "glow" at radio wavelengths, even at relatively low temperatures.

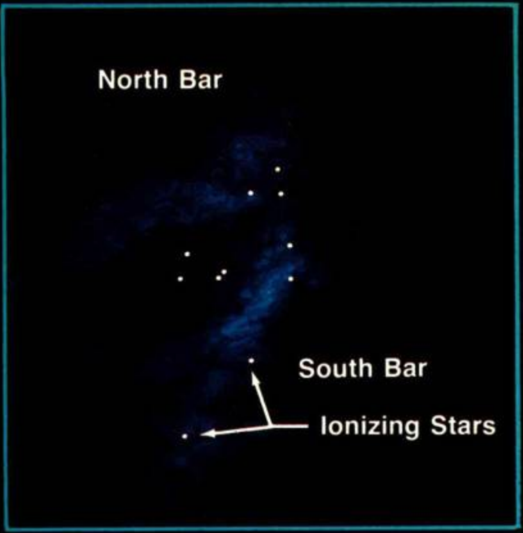
Without radio observations, astronomers can still often identify a cold, neutral cloud adjacent to an HII region. How? Since the ionized gas of the HII region is hot, it exerts a pressure that invades the molecular cloud. As the ionized gas expands, it crashes into the cold, neutral gas — and where they collide, the hot gas glows even brighter. The interface between hot and cold material is called an ionization front.

Ahead of the glowing ionization front is a region where the cold, neutral gas is violently squeezed — a shock front. Just as air piles up in front of a jet breaking the sound barrier, cold gas of the molecular cloud cannot escape quickly enough from the encroaching ionization front. The resulting "sonic boom" may be intense enough to trigger star formation in dense patches of cold gas.

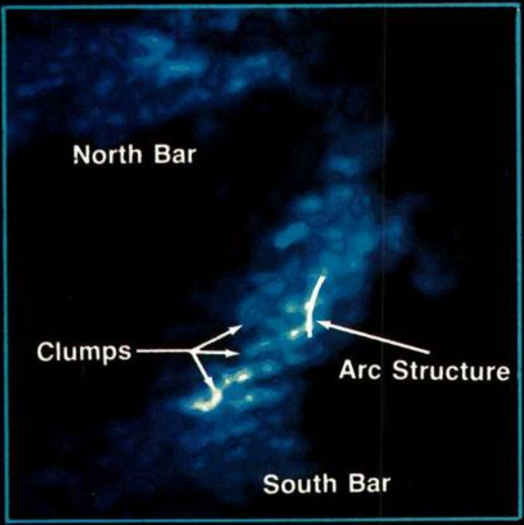
Applying New Techniques

Let's examine what's been discovered about nebulae with some new techniques. From April 1980 to March 1982, astronomers Marcello Felli, Ed Churchwell, and Maria Massi used the VLA to make high-resolution maps of the Omega Nebula in Sagittarius. At wavelengths of 1.3, 2, 6, and 21 centimeters

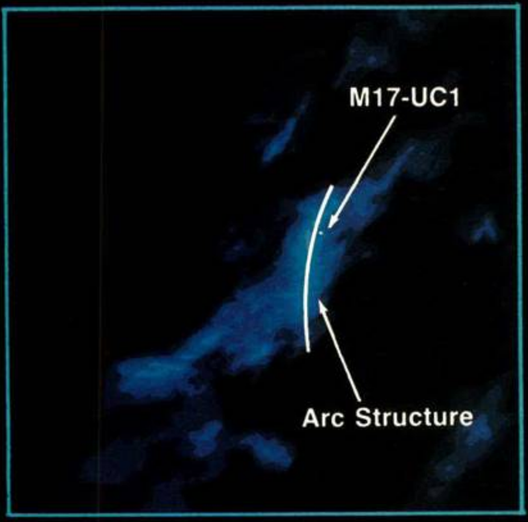
The Omega Nebula is merely the luminous part of a much larger molecular cloud to the west, designated as M17SW. Here, a radio map of carbon monoxide emission at 2.6 millimeters wavelength is superimposed on a photograph of the nebula. The molecular cloud extends well beyond the picture area to the south and west. Hot stars cause the visible part of the nebula to glow. Photo © 1965 Hale Observatories; radio data courtesy C.J. Lada, University of Arizona.



With better resolution, we can see two "bars" in the molecular cloud M17SW. Each bar is some six parsecs long and over one parsec wide. The northern bar closely corresponds to the visual location of the Omega Nebula. Hot stars in the neighborhood cause this part of the huge cloud to glow. Four hot, young stars provide 70% of the ultraviolet radiation needed to ionize M-17.

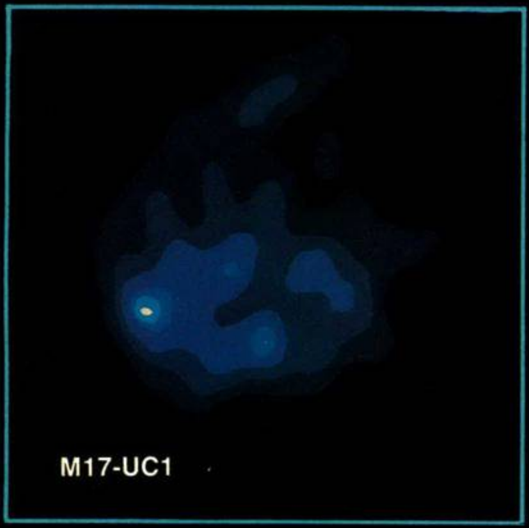


The sharp eye of the Very Large Array detected a complex network of clumps along the entire length of both bars. Since the glowing nebula is really just the "lit" portion of the molecular cloud, the entire molecular cloud probably has similar clumpy structure. The clumps range in diameter from 0.1 to 0.4 parsec. A single globule contributes a very small percentage of the total radio emission of the cloud.



This radio picture reveals the prominent arc-shaped ionization front in the middle of M-17's southern bar. The arc is 0.28 parsec long and 0.07 parsec wide; because of the geometry of the nebula, we see it almost exactly edge-on. The arc is about as dense as the shells surrounding one of the non-ionized globules, though much bigger. Also visible is the ultra-compact HII region M17-UC1, about 0.4 parsec to the west of the arc.

This high-resolution radio map of UC1, made with the VLA at 1.3 centimeters wavelength, hints at a shell structure. From the radio flux, astronomers derive its temperature as 12,000 Kelvins. Both the radio flux and the infrared emission from M17-UC1 suggest that a hot type-B star is ionizing from inside the shell.



A close-up of the arc and M17-UC1 at a radio wavelength of six centimeters. Both the structure and the location of M17-UC1 strongly suggest that this is an example of shock-induced star formation. The herringbone pattern is an artifact of the aperture synthesis technique used to create this high-resolution image.

Data Supplied by Authors

they made exceedingly detailed radio "pictures" of this nebula, which is one of the strongest "thermal" radio sources found in our Galaxy.

Also known as M-17, the Omega Nebula lies about two kiloparsecs away from the Sun at the edge of a very large molecular cloud called M17SW. Although this region has been studied extensively at optical, infrared, and radio wavelengths, the recent observations with the VLA uncovered some startling surprises about the internal workings of emission nebulae. The Omega Nebula is merely the light-emitting part of the large M17SW molecular cloud. This cloud is much colder (less than 50 K) than the HII region, so the hydrogen atoms in it are bound together as hydrogen molecules — hence the term "molecular cloud." The HI (non-ionized or neutral) regions in M17SW are dark and absorb the light of stars passing through them. Radiation from hot stars in the neighborhood causes part of this huge cloud — that part we see as the nebula — to glow. Four massive young stars now burn so brightly that they provide 70% of the ultraviolet radiation needed to ionize M-17.

Radio observations show M-17 is broken into two large intersecting bars, each about six parsecs long and one parsec wide. For convenience, astronomers have designated these as the northern, or N, bar and southern, or S, bar. The N bar corresponds to the location of the Omega Nebula, but the intersection of the bars and much of the bar is obscured by low-density gas and dust.

Lots of Clumps

The sharp eye of the Very Large Array detected a complex network of clumps along the entire length of both bars. Since the visible nebula is really just the illuminated portion of M17SW, the molecular cloud probably has similar clumpy structure throughout. Clumps range from 0.1 to 0.4 parsec in diameter; a typical clump is 0.2 parsec across. Each contributes only a very small percentage (less than 0.3%) to the total radio flux.

Astronomers Felli, Churchwell, and Massi concluded that the clumps — embedded in the hot, tenuous, and fully ionized gas of the nebula — are themselves cold, neutral globules of molecular gas and dust. The clumps typically contain more than 10 solar masses of material each, and are bright at radio wavelengths because the outermost shell of each clump is a hot, dense ionized envelope.

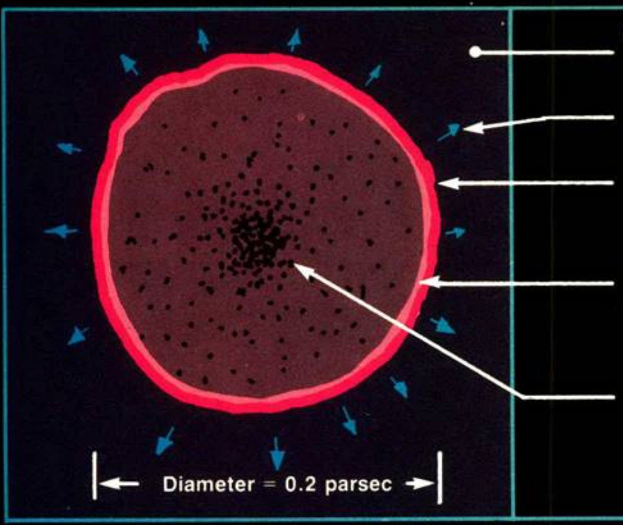
Finding neutral clumps embedded in hot HII regions is important for three reasons. Astronomers suspect that the most massive clumps are probably gravitationally unstable and will collapse to become stars in the future; hence, these objects are the precursors of stars. Second, during the lifetime of the ionizing star, the clumps continously replenish the more tenuous hot ionized gas in the nebula. Finally, since the clumps may have originated in the neighboring molecular cloud, the presence of globules in an HII region suggests that the associated molecular cloud also has clumps.

Why Do Clumps Exist?

The role of clumps in determining the structure and evolution of the HII region critically depends on their physical nature. If they are dense regions in the fully ionized gas, then they'll have little effect on the long-range evolution of the HII region. If, on the other hand, they are cold dense molecular globules surrounded by a thin ionized shell, the clumps may exert a profound effect on the structure and evolution of the nebula — and on the future stellar population in the region.

There is reason to believe the clumps are *not* density enhancements. First, there is no known way such density enhancements could form in HII regions. It takes work to compress the gas that makes them, and astronomers know of no reasonable way this could happen. Second, even if the clumps are fully ionized globules, they would have lifetimes lasting less than 10,000 years — a wink in the multi-million year life of a typical nebula. Because the clumps require densities about three times greater than the surrounding ionized gas to account for their radio brightness, their internal gas pressure must be proportionally higher. Since there is little to confine them, the pressure difference would cause them to expand into the

Anatomy of a Cold, Dense, Neutral Clump


Diameter = 0.2 parsec

Ambient HII Region
Temperature = 8,000 Kelvins
Density = 1000 Atoms/Milliliter

Outflow of Ions from Hot Envelope

Hot, Dense, Ionized Envelope
Thickness = 4 Astronomical Units = 30 Light-Minutes
Density = 100,000 Atoms/Milliliter
Total Mass = 0.01 Solar Mass

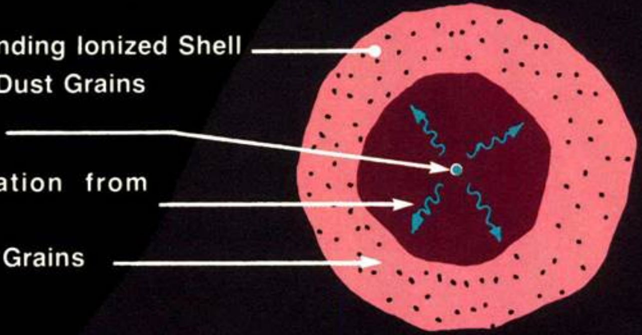
Shocked Neutral Gas
Density = 100,000 Particles/Milliliter
Temperature = 100 Kelvins
Thickness = A Few Light-Minutes

Cold, Dense Molecular Gas
Density = 100,000 Atoms/Milliliter
Temperature = 40 Kelvins
Diameter = ¾ Light-year
Total Mass = 10 Solar Masses

Forming and Maintaining an Ultra-Compact HII Region

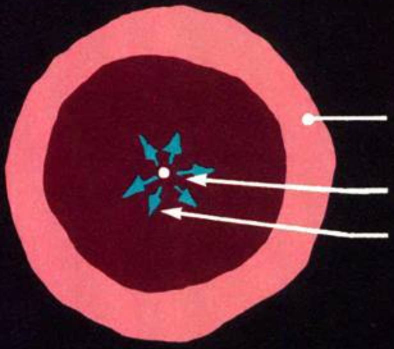
Radiation-Driven Shell

Radiation pressure on dust in the ionized gas drives the dust outward, dragging the gas with it. Proposed by Davidson and Harwit, 1969.

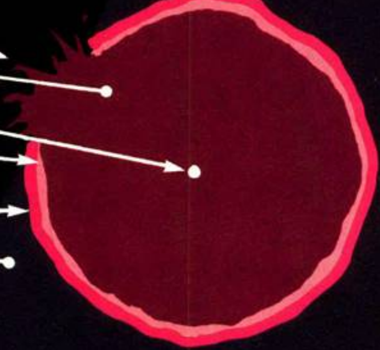

Expanding Ionized Shell with Dust Grains
Star
Radiation from Star
Dust Grains

Stellar Wind-Driven Shell

A flow of ions from the central star (a "stellar wind") collides with surrounding ionized gas, inflating a cavity around the star. Proposed by Weaver in 1977 and Shull in 1980.


Expanding Ionized Shell
Star
Stellar Wind

Blister-Type Bubble


Gas Outflow
HII Cavity
Star
Bright Ionization Front
Shock Front
Molecular Cloud

A developing star near the boundary of a molecular cloud forms an expanding cavity which breaks out of the cloud on one side, allowing ionized gas to escape. Proposed by Tenorio-Tagle in 1979.

surrounding low pressure gas, eradicating themselves in about 10,000 years. Unless the Omega Nebula has some fantastic "machine" for churning out clumps, their presence in M-17 rules out any possibility of them having short lifetimes.

The "cold, dense, and neutral" explanation for globules does not suffer from these problems. The clumps were probably formed in the molecular cloud M17SW, and then left behind as the ionization front of the HII region ate its way deeper into the cloud. These globules are so dense — more than 10^{11} molecules per cubic meter — that as the ionization front took the path of least resistance, it simply went around the clumps, and left them embedded in the tenuous HII region with dense, ionized shells.

Although the formation of clumps in a molecular cloud is poorly understood, several mechanisms could accomplish this under the conditions prevailing in a typical cloud. More importantly, though, direct radio wavelength observations of molecular line emission clearly establish that molecular clouds have clumps roughly the same size as those observed in M-17.

The Nature of Clumps

What do we know about the clumps? A typical clump has a mass well in excess of 10 Suns and a temperature of 50 K or less. Surprisingly, this means that a substantial percentage of the total gas in a supposedly hot, ionized, nebula's HI region is actually cold and neutral. The clumps continuously replenish the ionized gas in the region — since electrons and protons flow away from the thin ionized shell of each clump into the lower-pressure HII region. The result is that the nebula can maintain a high gas density throughout the lifetime of the ionizing stars by taking a steady trickle of material out of "high-density storage" in the clumps. This may explain why HII regions are long lived.

It seems strange — or at least contrary to common sense — that a neutral molecular globule exposed to enough ionizing flux to make an entire nebula shine would not be destroyed in short order. Calculations, however, show that the ionized envelope acts as protective blanket which absorbs UV radiation before it can penetrate very far into the clump. The denser this envelope is, the more effectively it protects the cold molecular gas inside. Calculations also show it would take more than a million years to destroy a typical globule in M-17, meaning that most of the clumps will outlive the brightest stars which now ionize the nebula!

The molecular clump interpretation would not work if the globules collapsed to form stars on time scales shorter than the lifetime of the nebula. If all of the clumps in M17SW were to form stars, this region would blaze with hot, young stars. The shortest possible time for a clump to collapse into a star is the *free-fall time* — the time it takes for a globule to fall in upon itself under its own gravity, unhindered by other forces. The absolute minimum for free-fall time is 10,000 years. The effects of internal pressure, possible rotation, and a possible magnetic field embedded in the clump's gases could increase the collapse time. Therefore, it's unlikely that the clumps are a source of runaway star formation; more probable is that the most massive clumps will form the next generation of stars in the area.

The Arc and the Clump

Deep in the middle of M17SW's S bar is an arc-shaped ionization front. This arc is 0.28 parsec long by 0.07 parsec wide; we happen to view it almost exactly edge-on. The arc is about as dense as the shells surrounding one of the neutral globules, but much more extensive. Nestled beside the arc, like a tiny blister, is the ultra-compact HII region M17-UC1. It lies some 0.4 parsec west of the arc.

M17-UC1 ranks high among new radio discoveries. It is an exceedingly small, compact — therefore very dense — HII region located close to a narrow, almost edge-on, ionization front within the S bar. Although astronomers have observed several other "ultra-compact HII regions," few are as dense as M-17's. Furthermore, no others are so clearly associated with an ionization front.

M17-UC1 may be ionized by a hot star at its center, rather than from the outside, as other clumps are. Because of its radio structure and location between the nebula and the molecular cloud, the central star was probably formed when a shock wave rammed into the cold, dense, molecular cloud ahead of the arc-shaped ionization front at the edge of M-17's HII region.

Shock-induced star formation is poorly understood, and clear-cut examples of the process are few and far between. Ultra-compact sources are the best candidates for shock-induced star formation, so it's especially important to determine their structure, formation, and evolution.

Getting Into M17-UC1

Both the structure and location of M17-UC1 strongly suggest that this object is an example of shock-induced star formation. And the new findings suggest that shock-induced star formation could be a major source of the stars near the borders between HII regions and molecular clouds. While shock waves aren't the only method of forming stars, perhaps they give the necessary nudge to these borderline cases.

In addition to helping us understand star formation, M17-UC1 also presents some interesting astrophysical problems. A high-resolution radio map of M17-UC1 at 1.3 centimeters wavelength hints that it is a shell structure with a temperature of 12,000 K. Taken together, the radio flux and the infrared emission from M17-UC1 reinforces the notion that a hot, type-B star ionizes the shell from *inside*.

However, the shell model for M17-UC1 presents a difficult problem. How is the bubble shape maintained? For the same reason that a density-enhanced clump will quickly expand and dissipate, an ionized shell of gas will expand both inward and outward until it achieves a uniform density. In the case of M17-UC1, this would take an extremely short time — only about 200 years.

How might such a shell be produced and maintain itself? Radiation pressure exerted on dust by the central star in the HII region may drag gas along by viscous forces to form a gas-and-dust shell around the newly formed star. Or a stellar wind (which could be especially strong from a hot, young type-B star) from the ionizing star could blow and maintain a "bubble." Or a cavity might also form by the ionization and heating of material around a newly-formed star which lies at the outer boundary of a molecular cloud. Without additional data, none of these possibilities can be ruled out, nor can we favor any one over the others.

Ultra-Compact HII Regions

At present, at least 18 ultra-compact HII regions have been discovered. All of these objects apparently have shell structures — which frequently appear around hot stars that have recently become self-luminous. Shells are not necessarily associated with the star-formation process involved, since M17-UC1 is the only ultra-compact HII region that is clearly an example of shock-induced star formation.

It is significant that the proportions of the observed shells are almost constant — that is, the ratios of outer to inner radii are roughly the same, even though the actual diameters vary 100 times from the smallest (M17-UC1) to the largest (W3A). If shell size is a measure of relative age, then it seems clear that shell structures last for long periods during the early phases of star formation.

New Frontiers

Shock-induced star formation is hardly a new idea. Several years ago, planetary astronomers looked at chemical anomalies in meteorites and began to suspect that the formation of our own solar system was triggered by the blast of a nearby supernova (see "Cosmic Contamination," ASTRONOMY, June 1980).

The most exciting discovery surrounding the Omega Nebula is the ultra-compact HII regions — these objects may tell astronomers a lot about the formation and early evolution of hot, massive stars.

We've come a long way from nebulae as mere "fuzzy smears in the eyepiece." New technology — new observing wavelengths, high resolution, computer imaging — has allowed us a more detailed look into the anatomy of a nebula. We have seen not only new small scale structures within the nebulae, but have also pinpointed challenging new observational and theoretical problems in our understanding of the universe.

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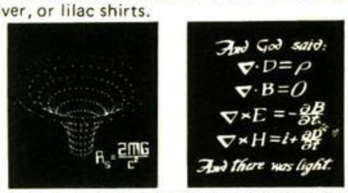
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WANTED — 1981 and 1982 editions of Teledyne Brown Engineering's "The Soviet Year in Space." Will pay reasonable price or trade for other space materials. Contact Tim Linder, 105 Edgewood Ave., Landrum, SC 29356.

WANTED — People interested in radio astronomy wishing to correspond with 14-year-old astronomy nut. Contact Chris Wilken, 545 Woodland Ave., Fairmont, MN 56031.

WANTED — TeleVue Nagler 9mm and 13mm oculars. Send description and quote price to C.G. Powell, 53 Hillside Ln., Mobile, AL 36608. Phone (205) 342-3192.

WANTED — Coulter 17.5" mirror with diagonal. Please send age, condition, and price to James Burr, 1960 Kerr Gulch, Evergreen, CO 80439. Phone (303) 526-9112.

WANTED — 13" or 14.5" f/4.5-5.5 thin mirror, elliptical secondary, 16" spider and cell, 8x50 right-angle finder, 2" rack and pinion, *eyepieces, Barlow, and color filters. Contact Ivan W. Martin,* 3298 Delooza Rd., Penn Yan, NY 14527. Phone (315) 536-8705.

WANTED — Optical glass blank suitable for making 4½" to 5" Maksutov corrector lens. Contact Gary Phelps, 226 High Ave., Oshkosh, WI 54901. Phone (414) 233-1699.

WANTED — *Someone (preferably with experience) on the east side* of Cleveland, Ohio to observe Halley's with. I have all my equipment ready, but can't find really dark skies in the area. Contact Earl Green, 3313 Silsby Rd., Cleveland Heights, OH 44118.

FREE — To owners of the *AAVSO Star Atlas*, a catalog of all deep-sky objects. Also wanted — correspondence with people interested in astronomy and computer programming. Contact Kevin Redden, Box 356, Vanceburg, KY 41179. Phone (606) 796-2315.

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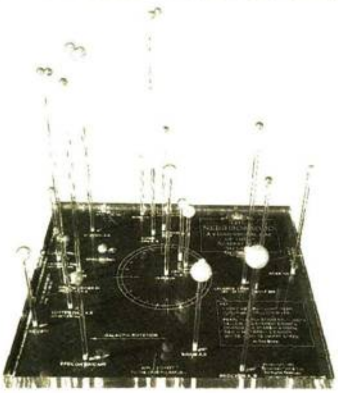

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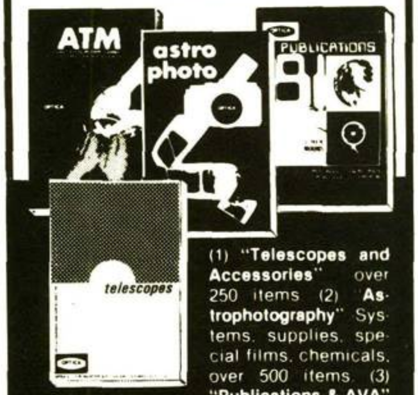

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The Dobsonian Dolly Transport System

by Terry Uselton

Well, congratulations. You finally finished it.

You step back, sheepishly grinning to yourself, and gaze at a truly remarkable instrument. After weeks of seclusion in the basement amid scraps of plywood, large sections of cardboard tube, empty shipping boxes, and crumpled-up back order slips — a telescope is born.

Your kids can now safely approach without you shouting "Look out, it's wet!" or "Don't touch the mirror!" In fact, now you want the whole world to see it. You gather the family around, all the while extolling the virtues of Teflon.

It performs beautifully as you sweep it through the celestial sphere with a single puny digit. You can even laugh off such comments as "What are these extra holes for, dear?" and "Can we seesaw on it, Daddy?" You — an amateur astronomer — are now the possessor of a 12½-inch telescope. Move over William Herschel! E.E. Barnard, watch out!

And to think, only months before you had laughingly (?) mentioned a second mortgage to your wife. Let's give a cheer for the Dobsonian revolution and domestic tranquillity.

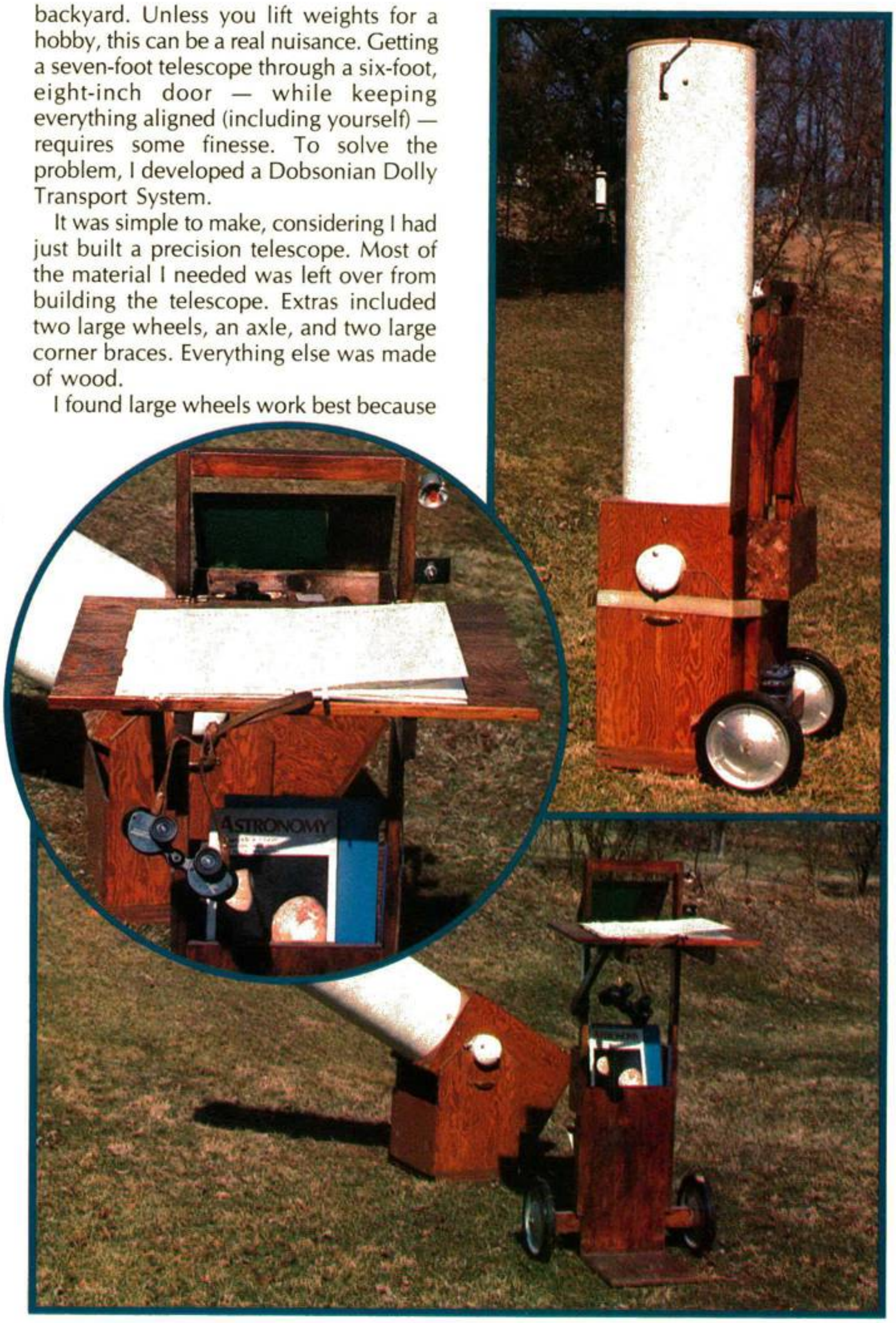
After reading the articles in ASTRONOMY on "How to Build a Dobsonian Telescope" (June and July, 1980), I knew I had to build my own telescope. Finally, I made a 12½-inch f/6 Newtonian — it performs beautifully and was well worth the effort.

To the average onlooker, probably the most impressive feature is the sheer size of a 12½-inch f/6 telescope. It looks like something out of an ironclad's turret. You have to be careful not to point it at a neighbor's house without adequate explanation. Unfortunately, size also carries a price — moving the scope about requires a small crew, and my family mutinied after the first few trips.

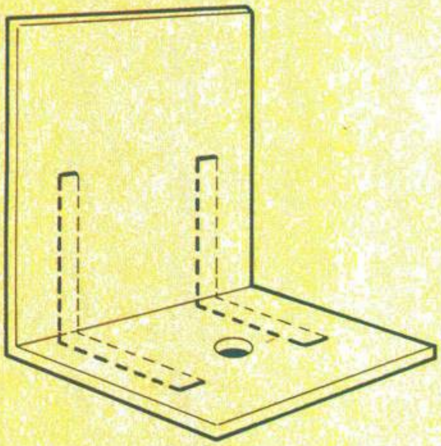
Now don't get me wrong — all the advantages of a big telescope certainly outweigh this one disadvantage. But you do face a problem in transporting it over short distances, such as out to the backyard. Unless you lift weights for a hobby, this can be a real nuisance. Getting a seven-foot telescope through a six-foot, eight-inch door — while keeping everything aligned (including yourself) — requires some finesse. To solve the problem, I developed a Dobsonian Dolly Transport System.

It was simple to make, considering I had just built a precision telescope. Most of the material I needed was left over from building the telescope. Extras included two large wheels, an axle, and two large corner braces. Everything else was made of wood.

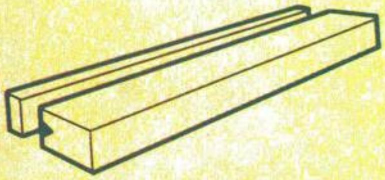
I found large wheels work best because



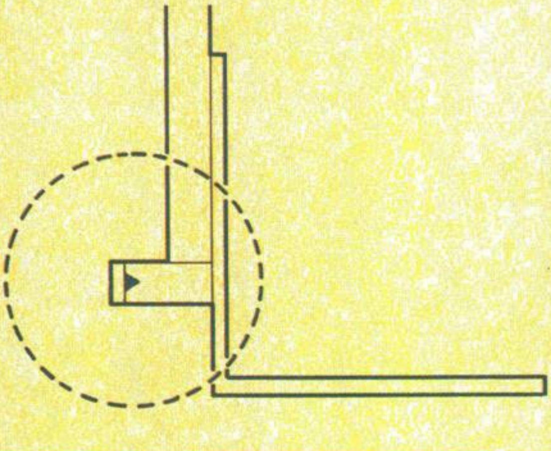
Step 1: Bottom Plate
The bottom plate is ¾″ plywood. Its width depends on the width of the bottom board of the rocker box. Fit the plate between the bottom board's feet and drill a 2″ hole to clear the rocker box's carriage bolt. Use 8″ corner brackets to strengthen the bottom.

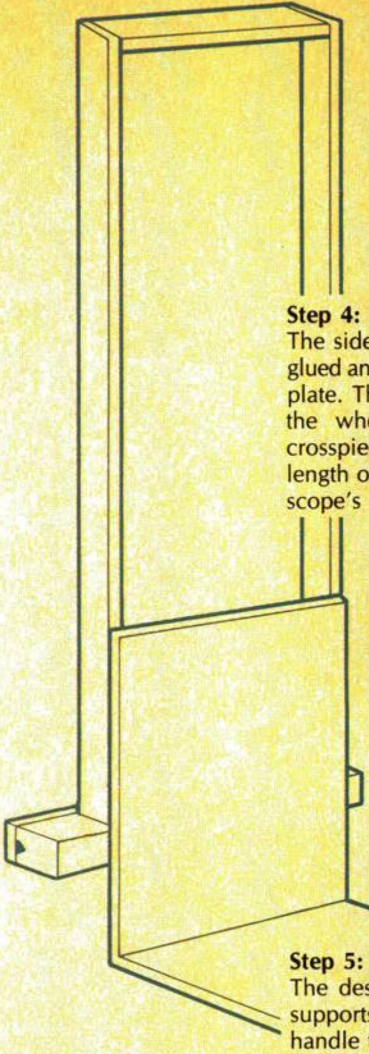


Step 2: Wheel Assembly
Cut a groove in a length of 1x2 or 2x2 wood for the axle and cover it with plywood. Insert the axle and slide on the wheels.



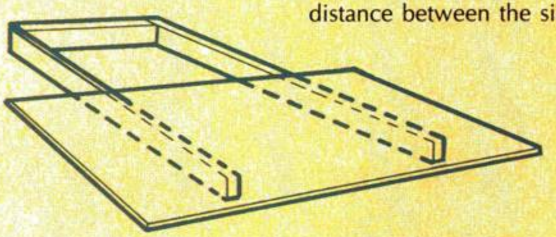
Step 3: Attaching Wheel Assembly
The wheel-and-axle assembly should be placed so that the bottom plate clears the ground by about half an inch. Make sure the wheel assembly is fastened securely!



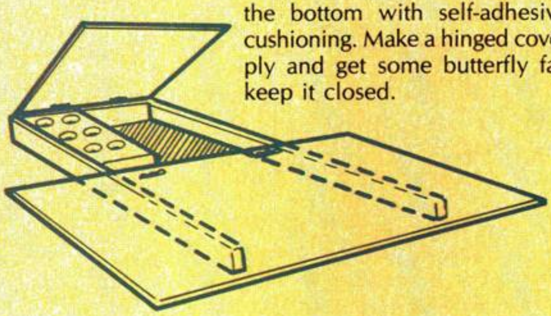


Step 4: Side Arms
The side arms are made from 1x2 strips glued and nailed to the back of the bottom plate. Their bottom ends should rest on the wheel assembly. Make a sturdy crosspiece at the top for a handle; the length of the side arms depends on your scope's size.

Step 5: Desk Top
The desk is a sheet of ¼″ ply, and its supports are 1x2s. Make it big enough to handle the sky charts you normally use, and put a small lip on the bottom end to keep stuff from sliding off. The width between the supports depends on the distance between the side arms.

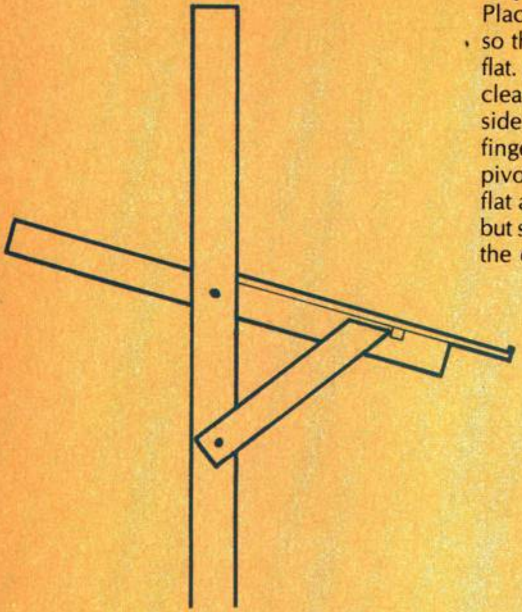


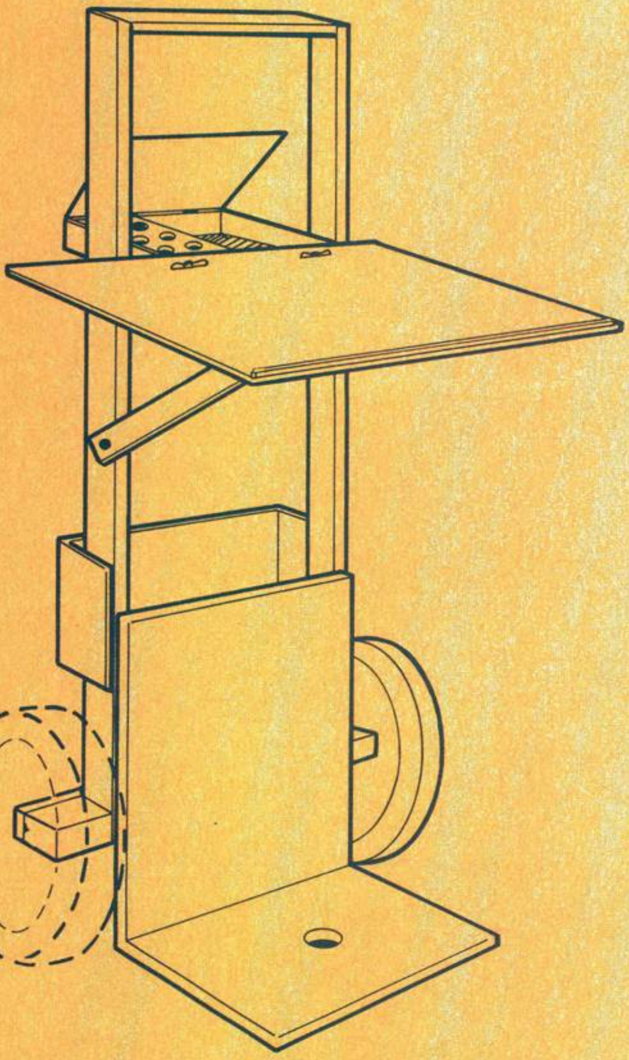
Step 6: Eyepiece Holder
At the back of the desk top support, make a small box out of ¼″ ply, placing inside it a piece of 2x4 drilled with 1¼″-diameter holes. (This is to hold eyepieces "at the ready" when you observe.) Line the bottom with self-adhesive felt for cushioning. Make a hinged cover from ¼″ ply and get some butterfly fasteners to keep it closed.



Step 7: Desk Top Brace

Place the desk top between the side arms so that it can swing down on bolts to lie flat. Make sure the box-end of the desk top clears the handle at the upper end of the side arms when stowed — leave yourself finger room. Next, attach one or two pivoting braces to the side arms. They lie flat along the side arms when not in use, but swing up to catch on a peg underneath the desk top.





they tend to reduce the jar caused by rolling over rocks, toys, flower beds, etc. Since the scope is fairly top-heavy, I also gave it a wide wheelbase to prevent it from turning over. (Who needs a heart attack?) I secure the scope to the dolly with an old seat belt.

Make sure the corner braces are sturdy, since they support most of the telescope's weight. I chose 8'' braces after rigorous field tests: when the clerks at the hardware store weren't looking, I did my best to bend them. Later, after the dolly was built, I made one final test before committing the scope to it — recruiting my kids as test subjects, we took a test drive around the yard. The dolly passed with flying colors.

And it works perfectly with the telescope attached. I can maneuver the scope anywhere without having to disassemble a thing. For a night's observing, all I have to do is round up my other assorted paraphernalia: eyepieces, star atlas, binoculars, notebook, red light, and so on.

Then another idea flashed through my head — ''Why not let the beast of burden carry everything?'' From that point, the idea began to snowball. ''Why not make it a complete work station!'' And that's what the final product became.

The dolly transporter now has the following features:

1. A folding desk top at a good work level.
2. A felt-lined eyepiece holder.
3. Roomy bookcase/carryall compartment.
4. Adjustable red light and switch.
5. Assorted hooks for binoculars, etc.
6. Self-contained electrical system.

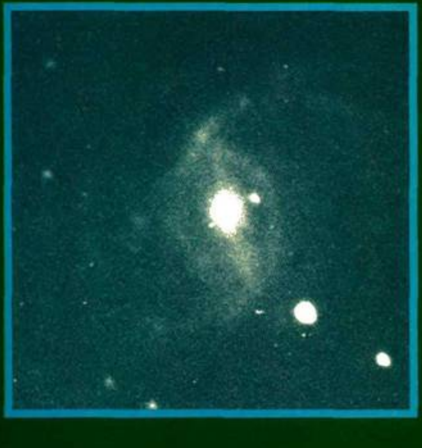
Other options I considered included an AM-FM cassette deck, utility jack for a blow dryer, electric socks jack, Thermos holder, sidereal clock, etc., etc. I guess I can always add some of these later. Astronomy sure seems to stretch your imagination, doesn't it? Who'd have thought I'd end up with a one-man rolling star party?

The directions tell how to build the basic model — additions and options are up to you. I haven't given specific measurements, since they depend on the size of your scope.

This transporter has been a most useful addition to observing. When the urge hits me, I just wheel out the telescope and I'm ready to go. No more little nuisance trips in and out of the house, and then wasting valuable time waiting for my night vision to come back. No more snide comments from friends about the fork lift I need for Christmas. Now I have a everything right at my fingertips and can leisurely cruise through the starry seas of the night.

Hey, wait a second — I bet the computer could go . . . .

Terry Uselton teaches chemistry and physics in Knoxville, Tennessee. His roll-around 12½-inch Dobsonian is the centerpiece of his astronomy presentations for area schools and local groups.



Above: As one of the sky's best globular clusters, M-5 offers a bright core and resolved edges to most backyard telescopes. Photo by Ben Mayer. Far left: The galaxy NGC-5921 appears as a bright core surrounded by faint nebulosity. Photo by Ron Potter. Left: The globular cluster NGC-5897 has a low surface brightness and is difficult to spot on less-than-dark nights. Photo by Martin C. Germano.

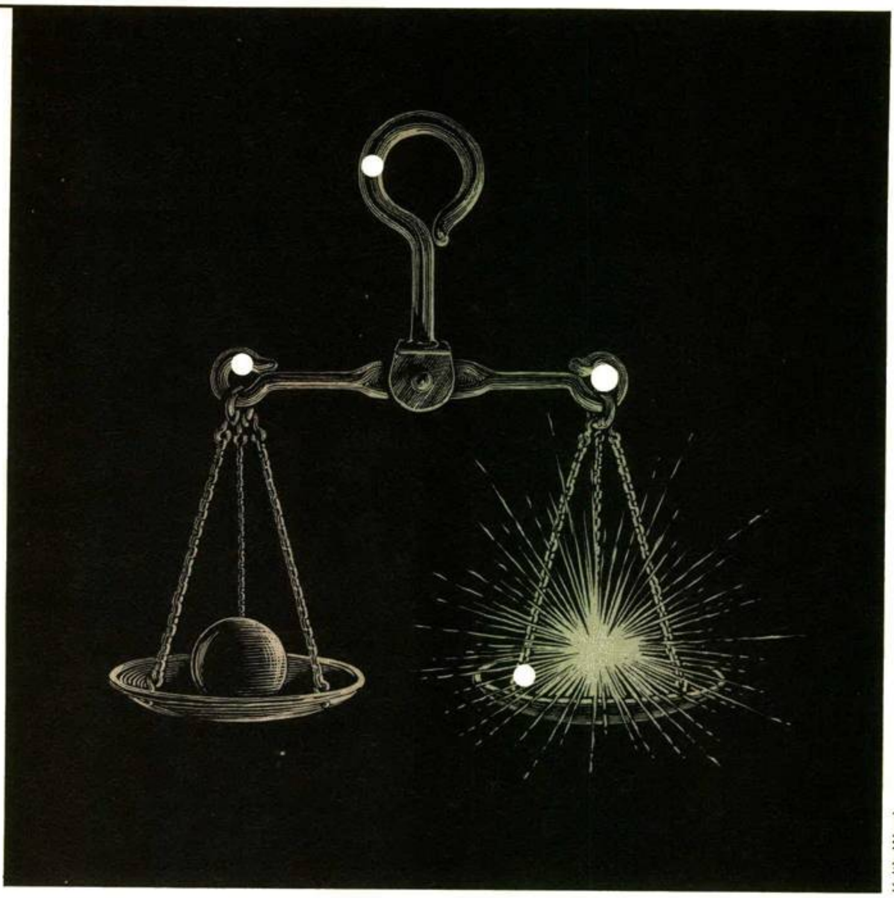
The Backyard Astronomer

Libra

Lib
Librae

Serpens Caput

Ser
Serpentis



Keith Ward

The region of sky containing Libra and Serpens Caput is overshadowed by the Milky Way's riches in nearby Scorpius and Sagittarius. Nevertheless, **Libra**, the Scales, and **Serpens Caput**, the Serpent's Head, both hold many small galaxies and each features a unique globular cluster.

Libra's most unusual object, **NGC-5897**, is difficult to observe owing to low surface brightness. It is a large, loosely-structured globular cluster lying in the south-central part of the constellation. Although NGC-5897's total magnitude is 8.6, its light is spread out over an area nearly half the Moon's diameter, making it appear extremely faint in small telescopes: only under very dark skies does a 4-inch telescope reveal NGC-5897, and a 6-inch scope doesn't show much more than a dim mottled patch of greyish-green light. A 12-inch telescope, however, distinctly shows the globular's large nebulous circle.

Because of NGC-5897's distance of 11.7 kiloparsecs, its brightest stars — red giants — glow weakly at fainter than 17th magnitude. It is impossible to clearly see individual stars in this cluster with a small backyard telescope. Even though NGC-5897 is not one of the most impressive globulars, the challenge here lies in simply finding the object.

Several degrees southeast of NGC-5897 is a diminutive planetary nebula known as **Merrill 2-1**. Skipped by the compilers of both the *New General Catalogue* and the two *Index Catalogues*, this object was discovered in the 1940s by astronomer Paul Merrill when he noticed its strong emission spectrum. Also studied by the Soviet astronomer Boris Vorontsov-Velyaminov, Me 2-1 is additionally known as VV 72. A problem with observing Me 2-1 is its tiny diameter: it spans a mere 7″, appearing as a star with anything but high power. It shines at about 12th magnitude and its elusive central star is estimated at magnitude 15.4. To find this small planetary, wait until a very dark, steady night. With a low-power eyepiece, find the nebula's approximate position. Now carefully study all objects of 12th magnitude — if one looks slightly fuzzy, switch to high magnification and see if your suspicions will be confirmed.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

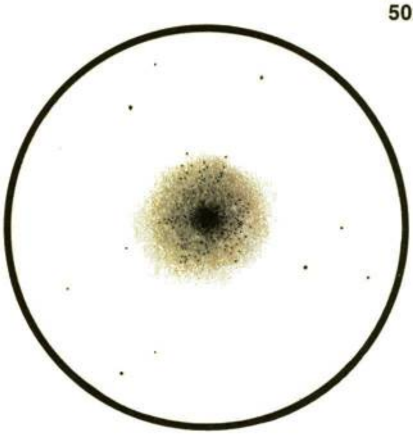
Libra also contains many small groups of galaxies. Lying between Zubenelgenubi (Alpha [α] Librae) and Libra's western border is the small Sc-type spiral **NGC-5595**. This petite galaxy shines at magnitude 12.4 and measures 2.0′ x 1.2′, making it visible as a fuzzy patch in telescopes as small as 6 inches in aperture. A 12-inch scope trained on NGC-5595 shows a small bright core enveloped in a smooth cottony halo. Just 4′ southeast of NGC-5595 is a companion galaxy catalogued as NGC-5597. This object is slightly fainter than NGC-5595, but — at 2.0′ x 1.8′ — it is also slightly larger. Its nucleus is quite bright and condensed into a nearly stellar ball of light. Both of these galaxies lie together in a group some 35 megaparsecs distant.

Midway between the NGC-5595/NGC-5597 pair and Zubenelgenubi is the fine barred spiral **NGC-5728**. In long-exposure photos, this galaxy shows a "theta" shape similar to that of the much brighter galaxy M-109 in Ursa Major. NGC-5728 shines at magnitude 11.3 and covers 2.8′ x 1.6′ of sky; it is an easy target for a good 6-inch telescope. The galaxy doesn't show much detail, however. All it reveals when viewed with a backyard telescope is a bright core surrounded by faint mottled haze.

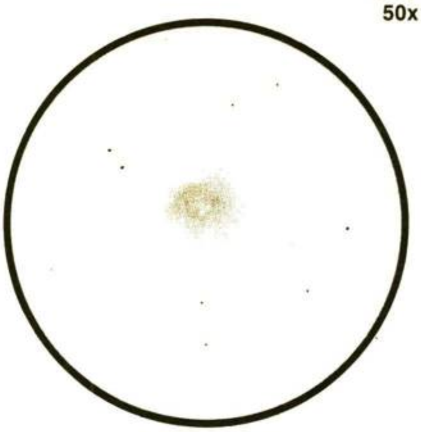
Three more galaxies lie in the central part of Libra. **NGC-5878** is a magnitude 11.5 Sb-type spiral measuring 3.5′ x 1.7′ across. Although easily visible in small telescopes, this galaxy generally appears as nothing more than a misty blur set against a barren starfield; its nucleus is diffuse and unconcentrated. **NGC-5861**, a 12th magnitude spiral, is somewhat more enticing: it measures 3.0′ x 1.8′, contains an unusually weak and motley nucleus, and features peculiar distorted spiral arms. These arms are not easily visible, but on a good night, a large backyard telescope — one in the 16-inch plus category — hints that strange disruptions are taking place inside this otherwise innocent-looking spiral. **NGC-5885**, a magnitude 11.7 spiral galaxy, is more typical. It's viewed nearly face-on, measures 3.5′ x 3.2′ across, and shows a bright stellar nucleus wrapped in a faint mottled circle of nebulosity.

The best galaxy in Libra lies in its northwestern corner. **NGC-5792** is a highly-inclined 12th magnitude spiral measuring 7.2′ x 2.1′. Easily visible in a 6-inch telescope on dark nights, it appears as an oval smudge of light with a bright stellar nucleus. Larger telescopes don't reveal much more structure in NGC-5792,

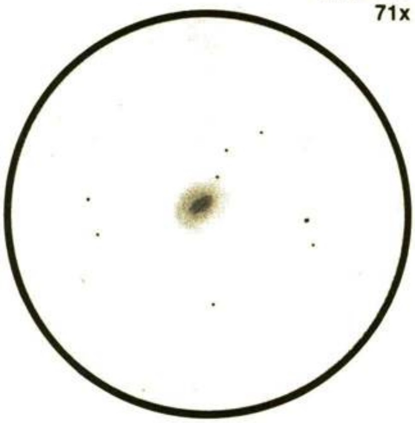
M-5 8-inch f/10 SCT 50x



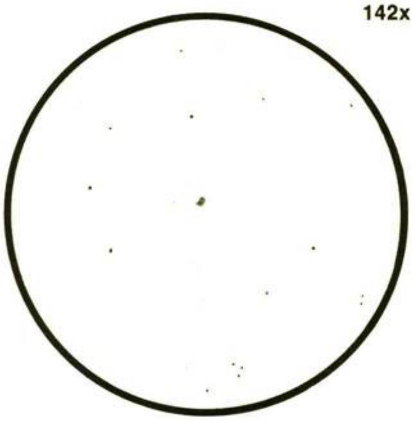
NGC-5897 8-inch f/10 SCT 50x



NGC-5921 17.5-inch f/4.5 reflector 71x



Merrill 2-1 17.5-inch f/4.5 reflector 142x



Sketches by David J. Eicher

but show its halo of nebulosity — the spiral arms — as knottier as telescope aperture increases.

An unusual star in Libra is **48 Librae**, the classic example of a so-called shell star, a late B or early A-type star which is slightly variable and shows peculiar emission lines in its spectrum. These features occur because the star is surrounded by a turbulent shell of gas whirling to and fro at velocities of 60 miles per second. This strange star is easy to observe, as it normally shines at magnitude 4.9. Its range of variance is slight: from magnitude 4.8 to 5.0.

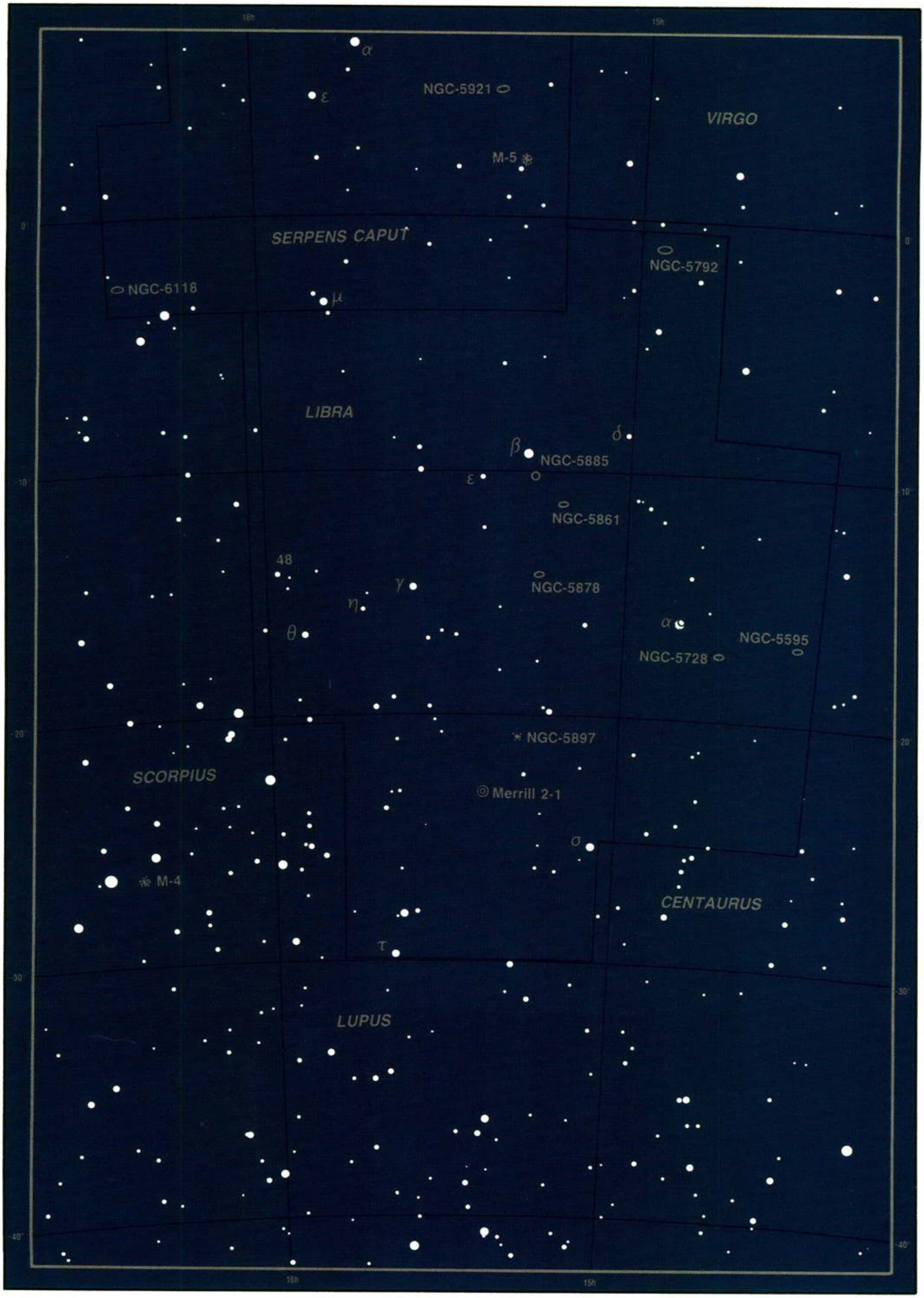
Serpens Caput's brightest galaxy is **NGC-5921**, a magnitude 10.8 barred spiral measuring some 4.9′ x 4.2′ across. This galaxy has a bright compact core surrounded by faint barred spiral arms, which are separated by dusty patches. Viewed in a backyard telescope of 5 inches' aperture, NGC-5921 looks like a small, roundish blotch of light with a bright center. A 10-inch telescope shows the nucleus as an intensely bright ball encircled by faint wisps of nebulosity suggesting spiral arms. A 17.5-inch scope at medium power reveals a mottled, indefinite spiral structure. **NGC-6118**, another bright galaxy in Serpens Caput, is a 12th magnitude Sb-type spiral. Its 4.7′ x 2.3′ dimensions make NGC-6118 visible in a 6-inch telescope on a dark night.

One of the finest globular clusters in the sky is **Messier 5** (NGC-5904), a large globe of stars shining at magnitude 5.8. M-5 measures 17.4′ across, corresponding to an actual diameter of 39 parsecs. It is fairly close as globulars go, lying high above the galactic plane 7.7 kiloparsecs away. Because it is so bright, M-5 is visible to the naked eye as a "star" under very dark skies. In binoculars, this unresolved patch of light appears as a fuzzy disk resembling an out-of-focus star. A good 3-inch telescope shows a bright glowing core wrapped inside a much fainter halo of nebulosity. A 6-inch scope at high power resolves the outer edges of M-5, revealing its stellar nature and transforming it into a fascinating object. Large backyard telescopes under dark skies resolve stars fully across M-5's face, providing unforgettable views.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
NGC-5595		§	14h 24.2m	−16°43′	12.5	2.0′x1.2′	Sc
NGC-5728		§B	14h 42.4m	−17°15′	11.3	2.8′x1.6′	SBb
NGC-5792		§	14h 58.4m	− 1°05′	12.4	7.2′x2.1′	Sbpec
NGC-5861		§	15h 09.3m	−11°19′	12.2	3.0′x1.8′	Sbpec
NGC-5878		§	15h 13.8m	−14°16′	11.0	3.5′x1.7′	Sb
NGC-5885		§	15h 15.1m	−10°05′	11.7	3.5′x3.2′	S
NGC-5897		●	15h 17.4m	−21°01′	8.9	12.6′	
NGC-5904	M-5	●	15h 18.6m	+ 2°05′	5.8	17.4′	
NGC-5921		§B	15h 21.9m	+ 5°04′	10.8	4.9′x4.2′	SBb
Merrill 2-1		■	15h 22.3m	−23°38′	12?	7″	
48 Lib		★^{S}	15h 58.2m	−14°17′	4.8-5.0	Irr	
NGC-6118		§B	16h 21.8m	− 2°17′	12.3	4.7′x2.3′	SBb

H = Hubble classification type for galaxies

★^{S}	*Shell Star*
●	*Globular Cluster*
■	*Planetary Nebula*
§	*Spiral Galaxy*
§B	*Barred Spiral Galaxy*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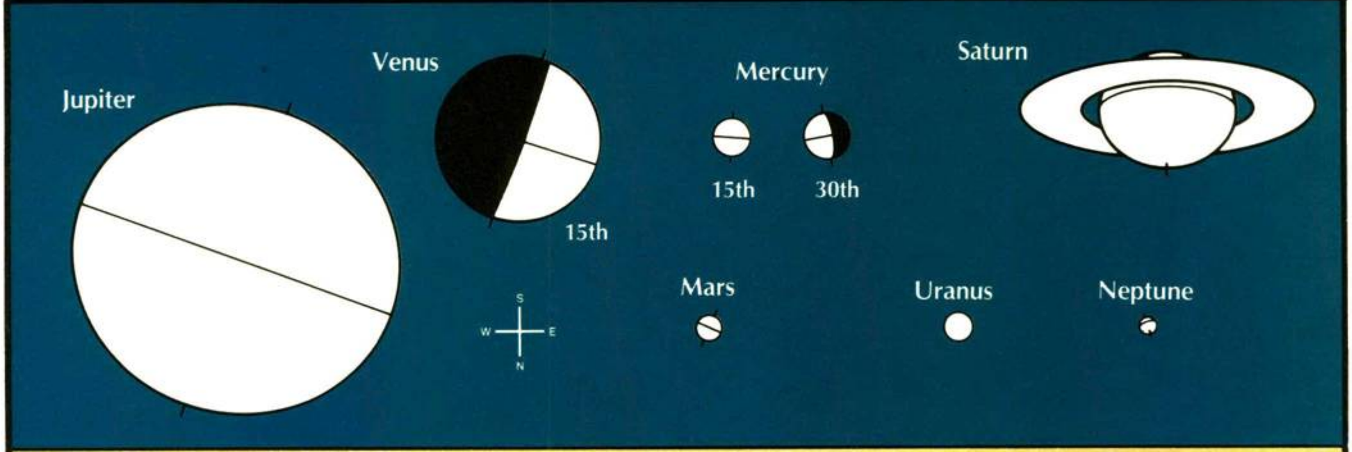
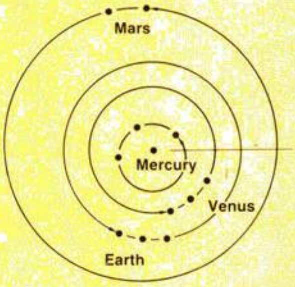
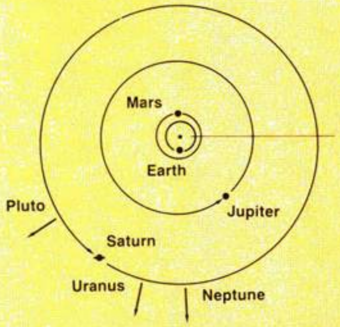
Planetary Data June 1985


Jupiter
Venus
15th
Mercury
15th
30th
Saturn
S
W
E
N
Mars
Uranus
Neptune

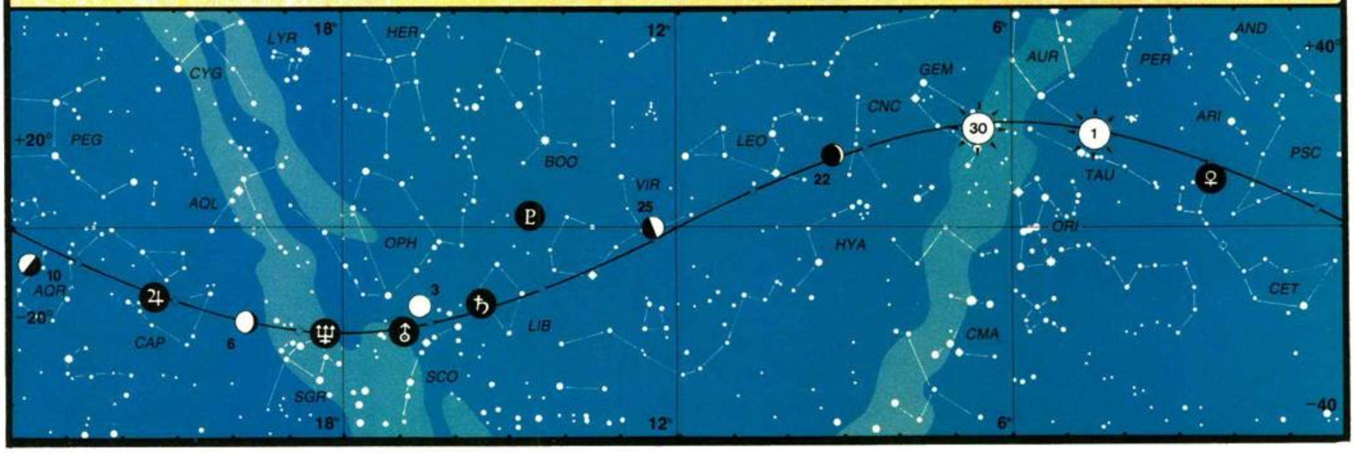
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.7	31.6′	—	1.01	—	—	70°27.7′	4h 36.2m	22°02.8′
		15	−26.7	31.5′	—	1.02	—	—	83°51.1′	5h 34.1m	23°18.5′
		30	−26.7	31.5′	—	1.02	—	—	98°09.9′	6h 36.4m	23°10.7′
Mercury	☿	1	−1.5	5.2″	95%	1.29	0.32	36°27.1′	62°45.4′	4h 02.7m	20°20.8′
		15	−1.4	5.2″	93%	1.28	0.32	122°17.4′	92°57.2′	6h 13.2m	25°06.2′
		30	−0.2	6.3″	66%	1.07	0.41	191°46.4′	120°25.6′	8h 12.2m	21°35.3′
Venus	♀	1	−4.4	27.5″	43%	0.61	0.73	286°42.4′	25°35.8′	1h 37.5m	7°56.7′
		15	−4.3	23.2″	51%	0.72	0.73	308°50.4′	38°23.6′	2h 27.4m	11°42.1′
		30	−4.2	19.9″	58%	0.84	0.73	329°24.7′	86°23.4′	3h 27.4m	15°52.8′
Mars	♂	10	1.6	3.6″	100%	2.57	1.59	97°35.1′	110°21.6′	6h 02.5m	24°17.6′
		20	1.7	3.6″	100%	2.60	1.60	102°21.2′	116°51.8′	6h 31.7m	24°09.2′
Jupiter	♃	15	−2.6	44.5″	99%	4.42	5.10	307°38.4′	314°45.5′	21h 18.7m	−16°24.0′
Saturn	♄	15	0.2	18.3″	100%	9.06	9.94	235°46.0′	231°46.4′	15h 24.6m	−16°16.6′
Uranus	⛢	15	5.5	3.9″	100%	18.08	19.08	256°05.3′	255°51.5′	16h 58.6m	−22°43.3′
Neptune	♆	15	7.9	2.3″	100%	29.25	30.25	272°11.2′	272°39.4′	18h 11.6m	−22°15.1′
Pluto	♇	15	13.7	0.1″	100%	29.15	29.76	213°43.9′	212°23.5′	14h 23.8m	3°45.5′


Mars
Mercury
Venus
Earth


Mars
Earth
Jupiter
Pluto
Saturn
Uranus
Neptune

Moon Data

Full Moon . . . . June 3 at 3h50m
Last Quarter . . . . June 10 at 8h19m
New Moon . . . . June 18 at 11h58m
First Quarter . . . . June 25 at 18h53m
Full Moon . . . . July 2 at 12h08m
Perigee: June 1 at 12h34m . . . . 360,917 km.
Apogee: June 13 at 14h5m . . . . 405,126 km.
Perigee: June 29 at 9h19m . . . . 365,768 km.


18°
12°
6°
+40°
+20°
−20°
−40
LYR
HER
CYG
PEG
AQL
BOO
VIR
LEO
CNC
GEM
AUR
PER
AND
ARI
PSC
TAU
ORI
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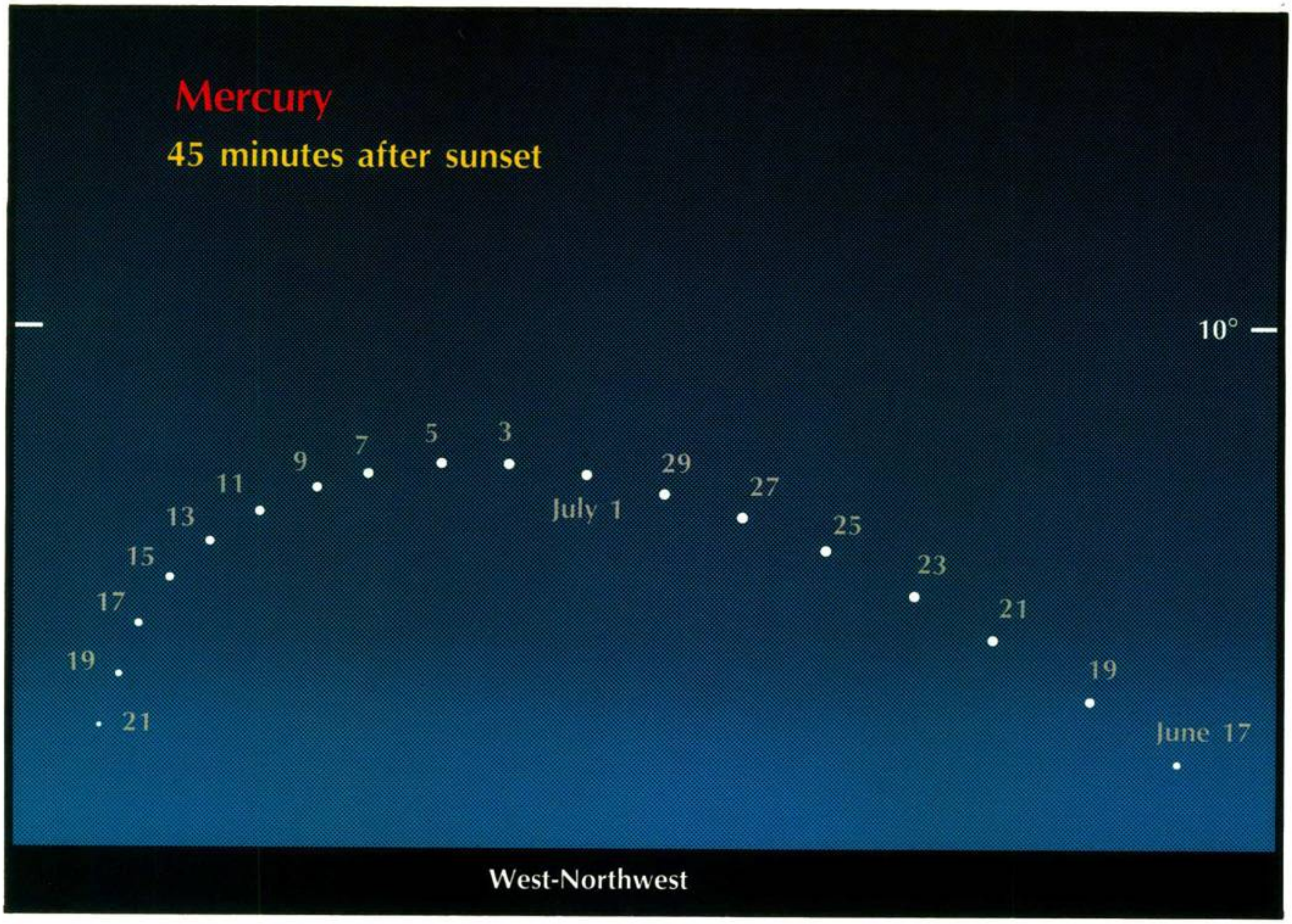


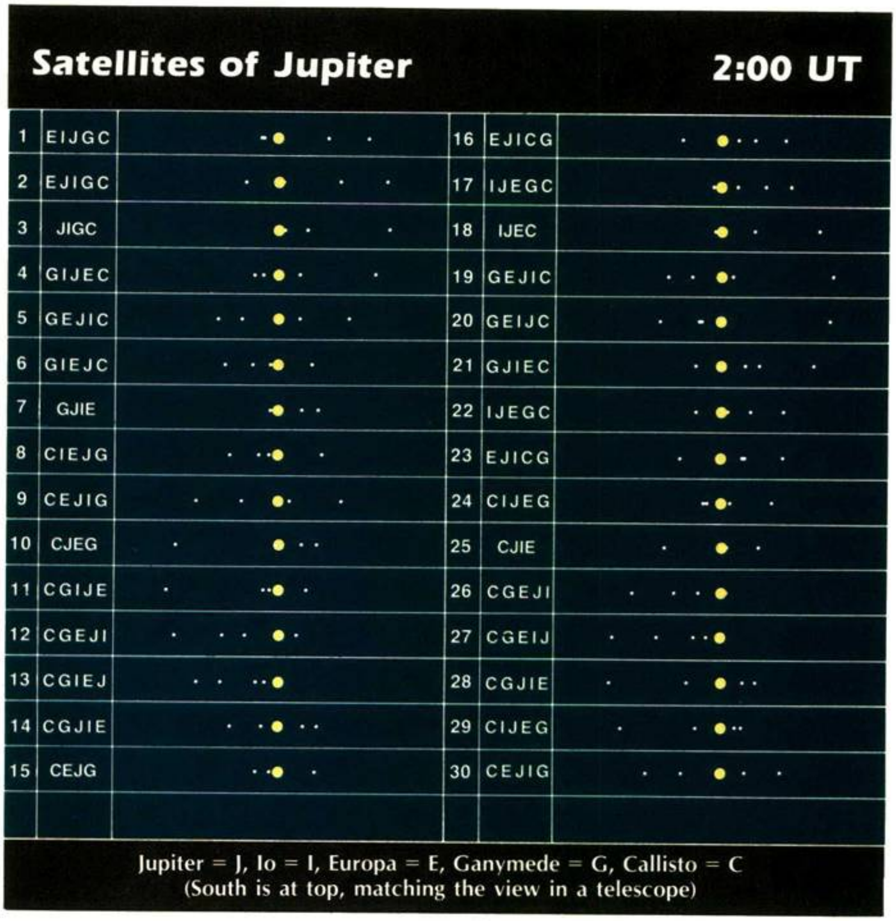
Between mid-June and mid-July, Mercury will be visible low in the western sky after sunset. To observe it with your telescope, you'll need a site with a low unobstructed horizon toward the west and northwest.

Mercury

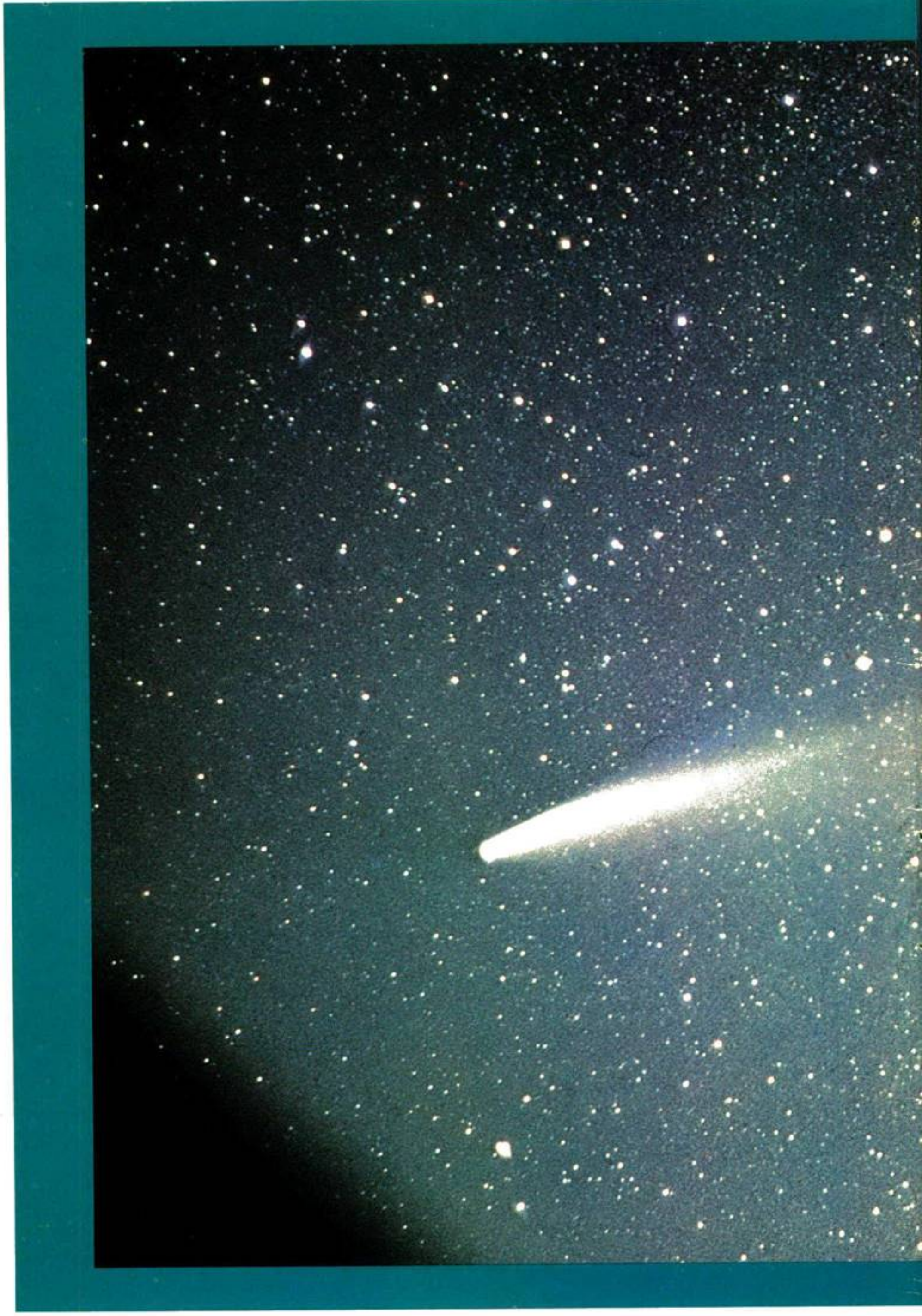
Although Mercury is in superior conjunction with the Sun on June 7th and won't reach greatest eastern elongation until July 14th, it will pop up into the evening sky about a month before then, becoming easily visible low in the west-northwest by about June 20th. Peak elevation comes on July 3rd: 8°, 45 minutes after sundown.

In a telescope, the little planet will show a small, featureless disk that will first appear gibbous. The phase will change day by day, becoming more like a quarter Moon and then a crescent. Since the planet will be very low, even at highest elevation, you should try to find it in twilight or while the Sun is still up.

With an equatorial mounting, offset from the Sun — use the coordinates as given in Planetary Data (see opposite page). With an alt-azimuth mounting, find Mercury soon after sunset and note its position relative to foreground objects. The next day, set your scope up in the same place earlier in the evening, start observing, and scan with a low-power eyepiece to the upper left of where you



Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)



This month's Best Astro-Photo award winner harks back to the spring of 1970 — when Comet Bennett (1970 II) made its appearance. Attaching his camera to an equatorial mounting, J. Peronto took this photo of the comet with a 57mm lens at f/1.4 using a 24-minute exposure on Ektachrome 64 film. Note the North America Nebula in the upper right.

saw Mercury the night before. A strong red photographic filter held over the eyepiece will darken the sky making Mercury easier to spot.

Venus

Bright Venus continues its steady upward climb in the morning sky. During June, a telescope will show it as half-lit, like a diminutive Last Quarter Moon. When the crescent Moon itself passes Venus on the 14th, it misses the planet by less than 2° — use your lowest power eyepiece to pack the two into the same field of view. A sequence of photos, centered on Venus and taken with a wide-angle lens — around 35 mm, say — at the same time of day on the 13th, 14th, and 15th would make a stunning and impressive sequence.

Earth

The solstice comes at 10h 44m UT on June 21st: summer begins in the northern hemisphere, winter in the southern.

Mars

Mars is too close to the Sun to be seen this month — conjunction is on July 18th — and it won't return for viewing until late August or early September.

Minor Planets

1 Ceres is in conjunction with the Sun on June 30th; it will be out of view until late July or early August.

2 Pallas (magnitude 9.5) is moving due eastward just south of the celestial equator near the juncture of Cetus, Eridanus, and Orion. Its positions:

10th: 3h 02m 58s, −0° 35.6′
20th: 3h 20m 42s, −0° 37.8′

Pallas rises around 4:30 a.m. local daylight time on the 15th — it will be hard to observe until late June.

3 Juno (10.8) is moving southeastward, paralleling the ecliptic about 8° to its north. The object is in central Virgo; its positions:

10th: 12h 07m 10s, 6° 36.4′
20th: 12h 12m 13s, 6° 04.3′

Juno sets about 1:30 a.m. local daylight time on the 15th.

4 Vesta (6.6) is also in Virgo, but to the east of Juno. On the 13th, it will pass 1m 44s of R.A. (26′ of arc) east of the third-magnitude star ζ Virginis. This is a good opportunity for you to catch the asteroid and follow it on its southeastward path. Its positions:

10th: 13h 35m 58s, −0° 09.5′
20th: 13h 38m 27s, −1° 20.7′

Vesta sets around 3 a.m. local daylight time on the 15th.

For convenience in plotting their motions on a star atlas, all minor planet positions are for the epoch 2000.0.

Jupiter

Jupiter is a prominent object in the morning sky, crossing the meridian during twilight. It lies among the stars of eastern Capricornus, but easily outshines them all.

The mutual eclipses and occultations of the four Galilean moons, mentioned last month, continue. The two best events — both requiring a telescope and medium-to-high magnifications — are an occultation of Europa by Ganymede on the 10th, and a partial occultation of Io by Callisto on the 24th.

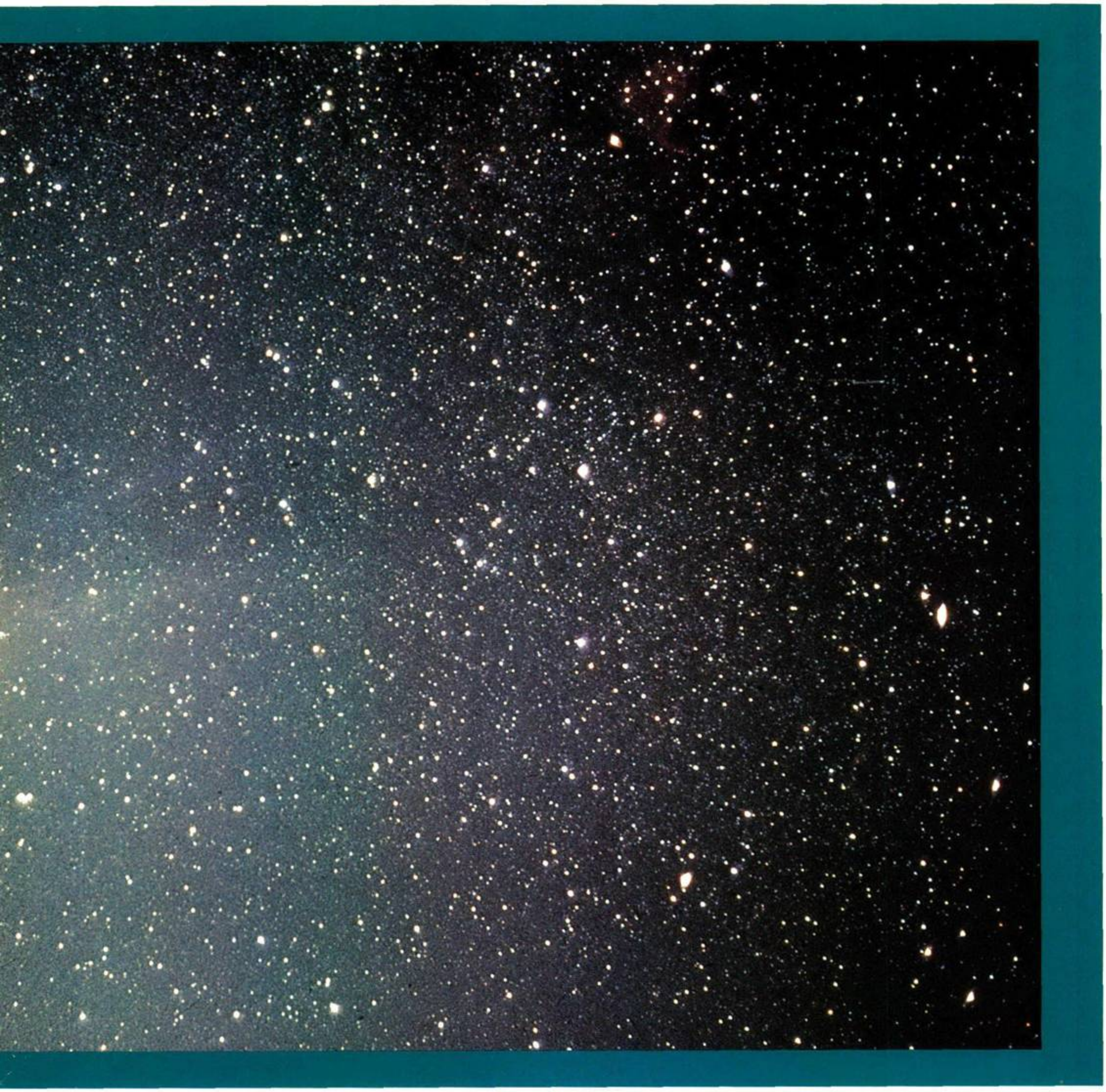
The Ganymede/Europa event occurs between 10h 09m and 10h 17m UT with a dimming of 0.5 magnitude. The moons will be 4 Jupiter diameters to the east of the center of the jovian disk. The Callisto/Io event (between 6h 02m and 6h 07m UT) has a drop in magnitude of 0.4, and occurs 1 Jupiter diameter west of the center of the disk.

Saturn

Like Jupiter, Saturn lies in a dim starfield — in this case, eastern Libra. At opposition on May 15th, Saturn is now well up in the southeast as evening twilight becomes night. In your telescope, you'll see the creamy-white ball of the planet, girdled by the broad "hat brim" of its rings.

Uranus

Moving slowing retrograde in southern



Ophiuchus, Uranus lies opposite the Sun in the sky on June 6th. It is just bright enough to be visible to the naked eye under an extremely dark sky — 5.5 magnitude — but a telescope is necessary if you want to confirm your sighting by observing the planet's 3.9'' of arc disk. During June, Uranus will be about 6° northwest of θ Ophiuchi, a 3.3 magnitude star plotted on the Star Dome map, pages 44-45.

Neptune

Also reaching opposition this month is Neptune, which is in Sagittarius about 3° to the northeast of the Lagoon and Trifid Nebulae. (These are plotted on the Star Dome map as M-8 and M-20, respectively). Neptune's opposition date is June 23, when the planet will be at magnitude 7.9.

Although its brightness falls within the reach of most binoculars, a telescope is the best instrument to use for identifying this object. Neptune's disk is only 2.3'' of arc across and will look stellar with any magnification less than about 100x.

Meteors

June has several minor showers that offer 2 to 5 meteors per hour, but the best is the so-called "June" Lyrids. Like the better-known shower in late April, these also come from Lyra, though from a somewhat different location on the sky. The June Lyrids aren't very plentiful — zenithal hourly rates range from 5 to 20 — but the Moon won't be a problem on the date of peak activity, June 15th, since it is just 3 days before New.

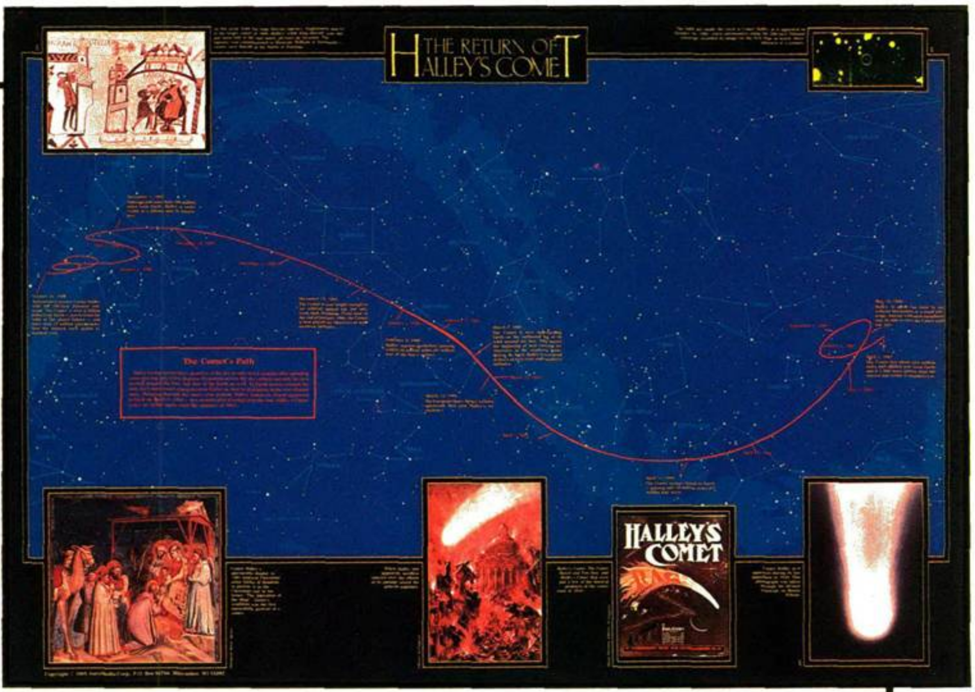
Comet Halley

The famous comet is in conjunction with the Sun on June 12th; it is in Taurus, just above the head of Orion. Halley's positions (epoch 2000.0):

10th: 5h 21m 39s, 17° 40.6'
20th: 5h 27m 53s, 17° 58.4'

On the 15th, Comet Halley's magnitude (a meaningless figure, actually, given its proximity to the Sun!) is 15.0. For more on viewing the comet, see "Observing Prospects for Comet Halley," page 35 of this issue.

Display Comet Halley On Your Wall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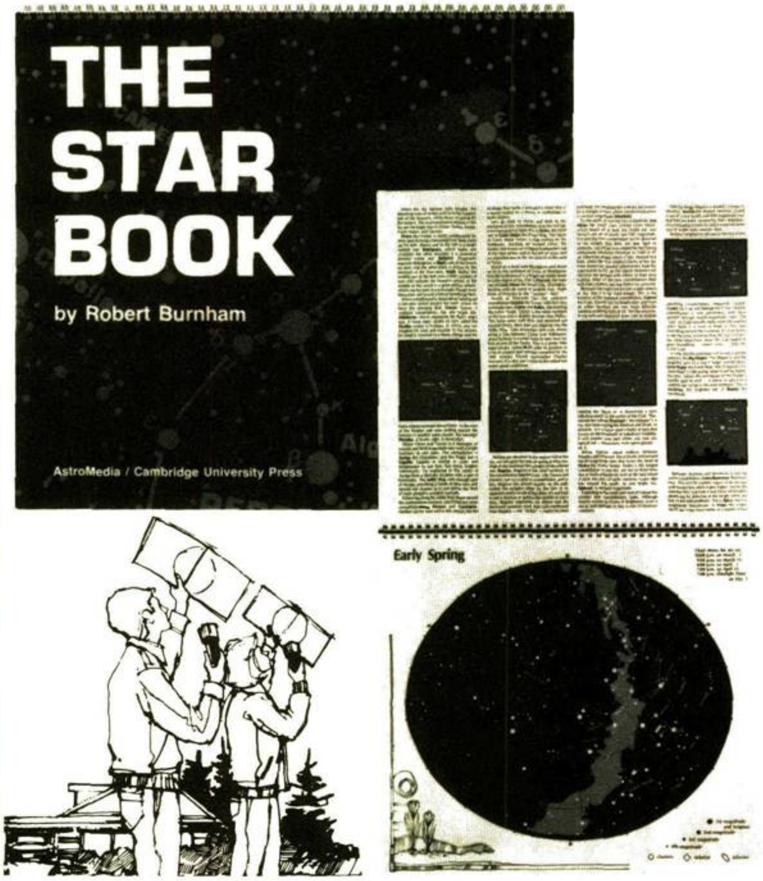
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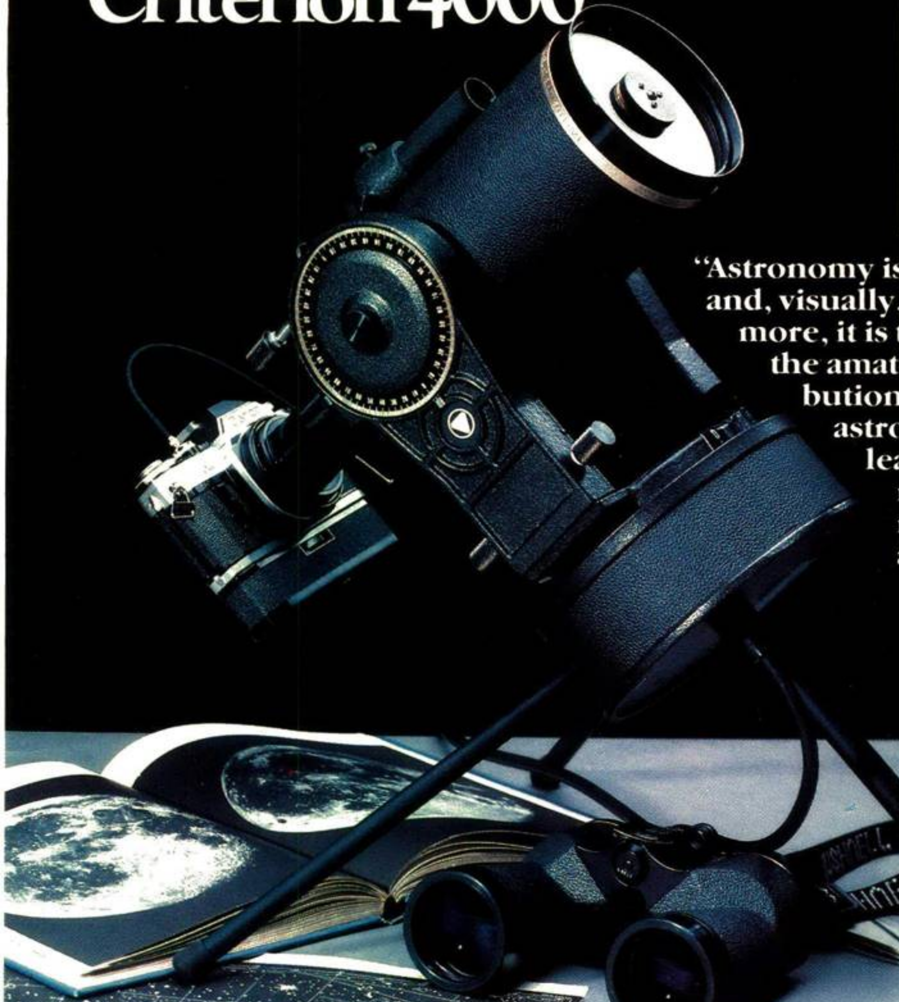

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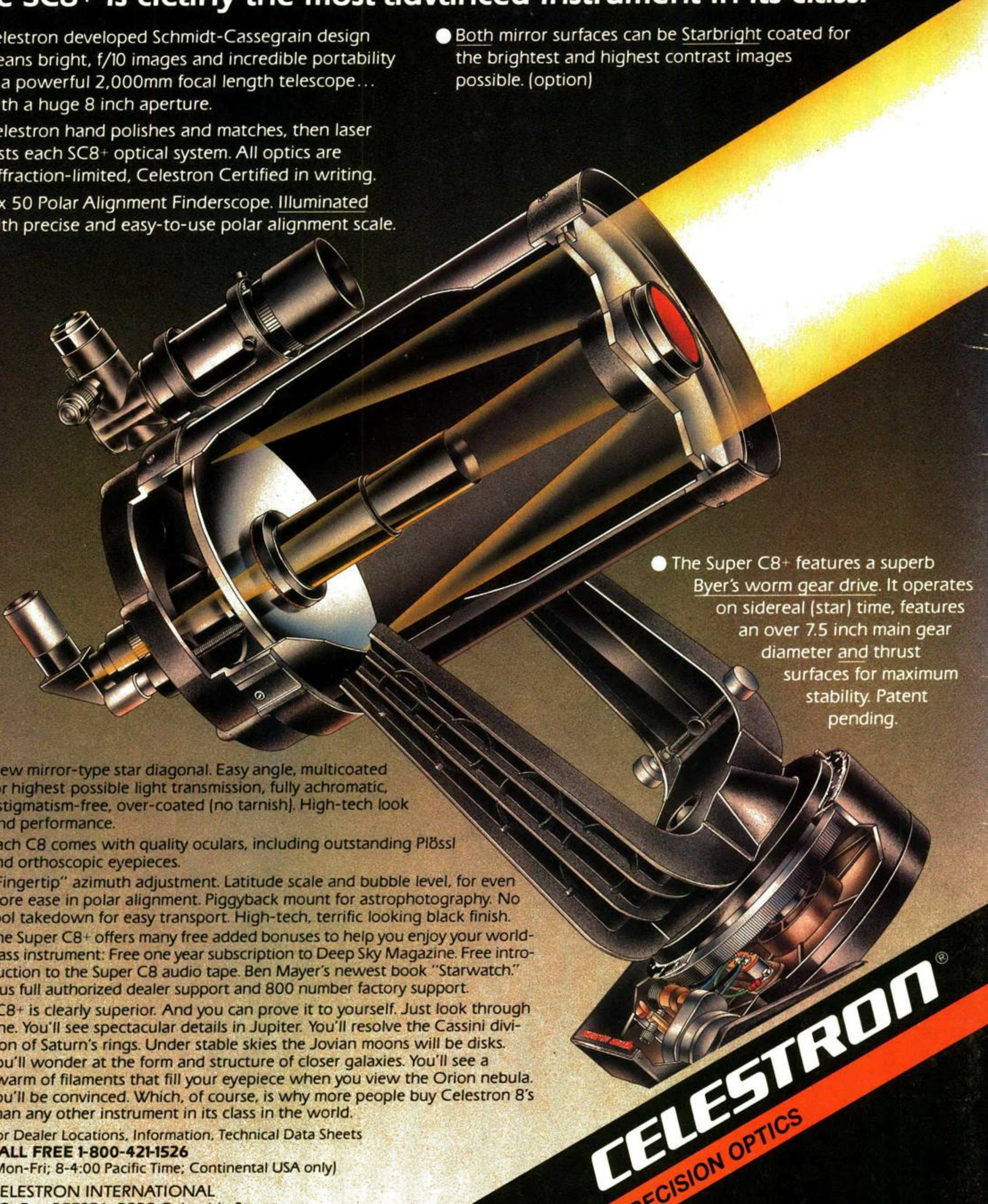

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